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CONTENTS OF VOLUME VIII.

	PAGES.
PART I.—Report on Lac and Shellac, by H. A. F. Lindsay and C. M. Harlow	1—162
„ II.—The Regeneration of Sal (<i>Shorea robusta</i>) Forests. A Study in Economic Oecology, by R. S. Hole	163—228
„ III.—The Beehole Borer of Teak. A preliminary note on the ecology and economic status of <i>Duomitus ceramicus</i> , Wlk. in Burma, (<i>Lepidoptera, Cossidae</i>), by C. F. C. Beeson	229—333
„ IV.—Notes on Artificial Regeneration in Bengal, by Messrs. A. K. Glasson, P. T. Russell, E. O. Shebbeare and L. E. S. Teague	334—366
„ V.—The Essential Oil from the leaves of <i>Abies Pindrow</i> , Spach, by John Lionel Simonsen	368—372

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PREFACE

The writers of this report are indebted to the late Mr. F. M. Howlett, Acting Forest Zoologist at the Forest Research Institute and College, Dehra Dun, for much valuable help rendered in connection with the report. To him are due the final form of Chapter I; Appendix III, containing suggestions for research; and the illustrations to Chapter VIII.*

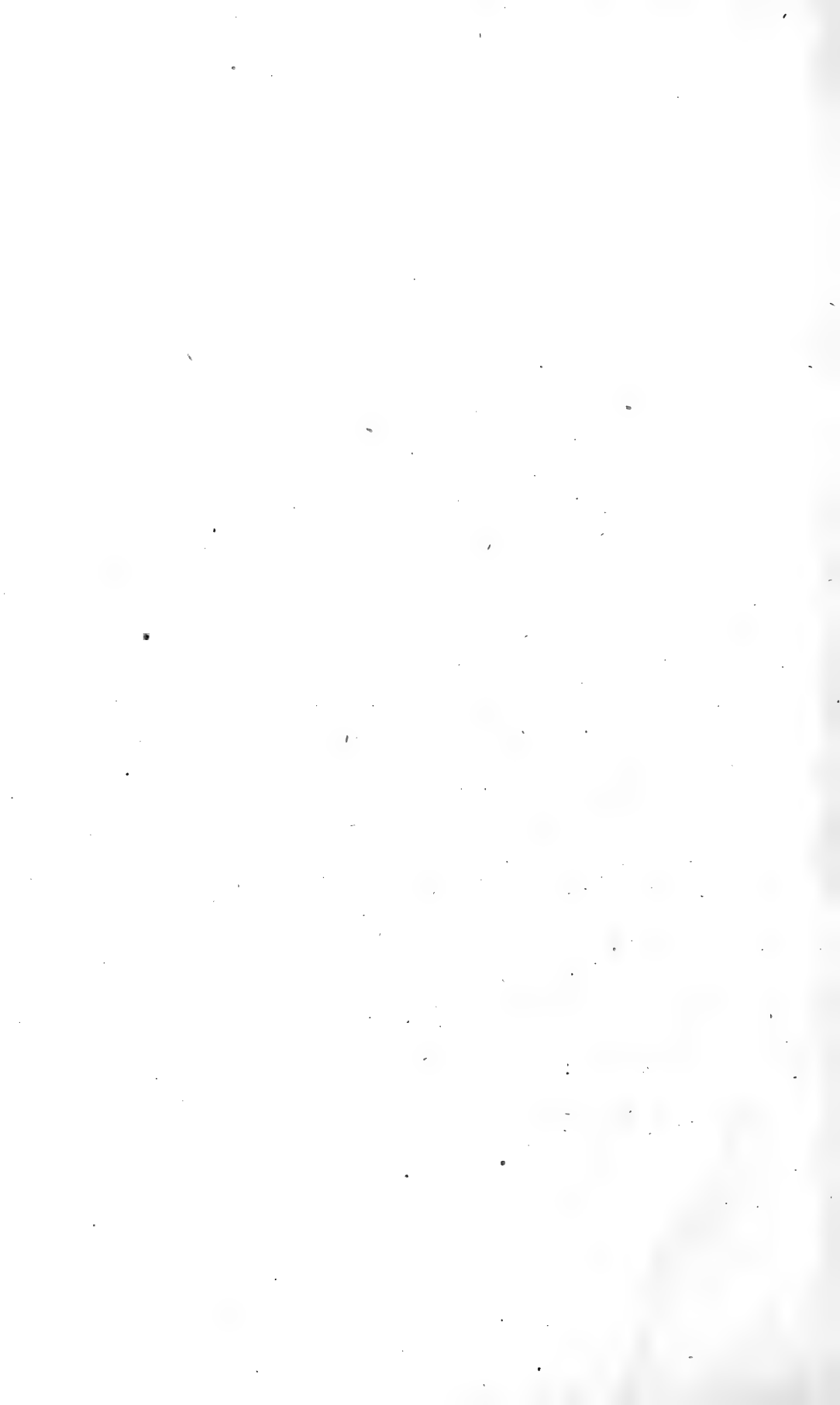
Acknowledgments are also due to the Indian Trade Commissioner in London for valuable information received from the London, New York and Berlin markets; to Mr. G. C. Baker of Messrs. Angelo Bros., Mr. S. Bromley of Messrs. Kilburn & Co.'s Rookhur Ghat Factory, Mirzapur, and to Mr. L. De Bretton of Messrs. Becker Gray and Co., for much assistance and advice. Messrs. Moran and Co. kindly supplied the statistics of London stocks, of prices and exports.

Finally we are much indebted to revenue and forest officers in the districts and to firms in Calcutta and up-country, too numerous to specify.

DEHRA DUN :
The 12th May, 1920. }

H. A. F. L.

C. M. H. ^a



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INTRODUCTION.

The lac industry has passed through many developments and has experienced many turns of fortune. From ancient days lac-dye was held in high esteem for its bright red colour, and the name still lingers as Crimson "lake." Two generations ago, however, it began to yield place to vegetable and chemical substitutes and, within the space of a few years, the trade had dwindled to nothing. In 1868-9 the exports from India were valued at nearly eight lakhs of rupees; ten years later, they had diminished by one-half in volume and their value stood at only two lakhs. Luckily the value once attached to the dye passed with interest to its resinous by-product lac, which has been in demand since early days for varnishes and polishes, and during the current century for other purposes also, such as gramophone records and the manufacture of electrical apparatus. In 1888-9, when exports of the dye had practically ceased, the exports of shellac, which is lac manufactured in flake or "shell" form, were valued at nearly thirty-two lakhs of rupees. Ten years later the value of the trade had risen to over seventy lakhs, and ten years later again, in 1908-9, a total of nearly two and a half crores was reached.

The history of the trade is not, however, one of steady progress, for it has always been liable to serious fluctuations of price. The reasons will be given later in some detail. For the present, it will suffice to remark that the lac industry is very widespread in India, which is practically the only source of supply; that cultivation is everywhere in the hands of village labourers, of little education and scanty means, who neglect the crop when prices are low and are too often tempted, when prices rise, to strip their trees of the brood-lac on which subsequent production depends; and that, as a result of these and other factors, while foreign markets can be quickly glutted, they are nervous of a shortage at their only base of supplies; and prices oscillate violently in consequence. It is moreover an interesting feature of the trade that the London and Calcutta prices follow closely, in inverse, any important variations in the quantities stored in London warehouses; for such variations afford a safe index to the strength or weakness of the demand.

On the outbreak of war, London stocks had attained the very high figure of nearly 100,000 cases and the price was only 61s. per cwt. Normal commercial demands were cut off and at first the military demand for shellac, for the inner coating to shells and for electrical and other fittings, was not of itself sufficient to stimulate the trade. By August 1915, London stocks and prices were much what they had been the year before, and it was not until 1916 that stocks were reduced; on the 1st December of that year they stood at 56,000 cases, while the price had risen to 139s.

By this time, the military demands for shellac on account of Great Britain and the Allies had increased; and, in view of the serious rise of prices in London, measures of control became necessary. In December 1916 a delivery price of Rs. 42 per maund for Government shellac f.o.b. Calcutta was agreed to at a conference between Government and the principal Calcutta shippers. Open market prices in Calcutta were more than double that rate, and the loss on each Government consignment was made good by the shipper on his sales to foreign consumers.

Although, throughout the period of control, Calcutta prices remained fairly constant between Rs. 90 and Rs. 100 per maund, the London price steadily increased from 144s. in January 1917 to the enormous figure of 450s. per cwt. in April 1918, by which time the stocks had declined from 54,000 to 18,000 cases. Thereafter supplies improved slightly and by December 1918 the price had fallen to 320s. These prices, of course, represented the rates which the private consumer in London was willing to give against declining stocks with no near prospects of replenishment. The Ministry of Munitions had throughout secured its supplies at the Calcutta price of Rs. 42 per maund, plus the usual freight and handling charges.

In December 1918, war control came to an end and the reversion to normal conditions began. Although foreign markets were starved of lac, it was naturally some time before the various manufacturing industries recovered sufficiently to stimulate the demand. Moreover, Government was known to possess considerable stocks and this knowledge depressed all markets. The London market fell from 303s. in January 1919 to 205s. in April. Subsequently there was a recovery as the various industries consuming shellac awoke to their former activities. From that month London prices rose steadily again, the

rise being accentuated by poor crops and short supplies in India during that year. Early in December the price was 570s. and in January 1920 it touched 880s. With every indication of a bumper crop coming forward, prices have since declined. There is no doubt that they had reached an unhealthy level and all in India who have the true interests of the industry at heart are anxious for a reversion to normal levels and normal trade conditions.

From the stand-point of May 1920, one may review the present position briefly as follows:—

The war has naturally altered both the value and the direction of India's lac trade. During 1912, a typical pre-war year, the total exports stood at 254,000 cases. The principal customers were:—

					Cases.
The United Kingdom taking	...	...	...	...	50,000
The United States taking	...	...	...	...	111,000
Germany, Holland and Austria taking	...	...	...	...	63,500
France taking	...	...	...	...	16,500

During 1919, a year when the crops were poor and freight space still short, the total exports amounted to 205,000 cases.

Germany and Holland took only 450 cases direct from India, and the principal customers have now become:—

					Cases.
The United Kingdom taking	...	...	...	...	56,000
The United States taking	...	...	...	...	139,000
France taking	...	...	...	...	5,450
Japan taking on transit for the western ports of America...	...	...	...	...	600

The 1920, crop prospects are good, but foreign consumers are buying freely and the reduction in the German demand is not noticed. No satisfactory substitute has appeared on British or foreign markets, even under war compulsion. In short, all foreign conditions are favourable to the industry of which India holds what is virtually a world's monopoly.

No monopoly in the world, however, can be considered permanently safe. The greater its value, the greater the inducement to the manufacture of rival products. The importance of lac to many manufacturing industries of the West, and its present high value, expose it to serious risks of attack. Unfortunately, also, the industry is encrusted with local prejudice and handicapped by unscientific methods.

is widely scattered over India. The principal districts of production alone, where cultivation is concentrated, cover a greater total area than that of the British Isles. The propagation and collection of lac are still primitive and uneconomic, manufacture is careless, adulteration rife. Prices fluctuate seriously from season to season ; and, in the absence of authoritative reports on crop conditions, speculation flourishes. A wider knowledge of scientific methods and a closer organisation are necessary to stabilise the trade.

These are the circumstances in which the present enquiry was ordered by Government. Fortunately, as the defects are generally primitive, so are the remedies in most cases simple; and the real object in view, namely to stimulate production on economic lines, is one which must appeal to all interested parties whether cultivators or manufacturers, dealers, brokers or merchants.

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[Part I

CHAPTER I.

THE LAC INSECT.

No one has suggested a better derivation of the word "lac" than that from the Sanskrit *Laksha* (Hindi Lakh) meaning a hundred thousand. The allusion* is to the vast numbers of minute lac insects which emerge at the period of swarming and settle on the young shoots of the "host"-tree, to suck its juice and exude the lac of commerce.

The following brief account of the insect is offered only as a necessary preliminary to subsequent remarks and recommendations on the subject of cultivation, collection, manufacture; and research. For, although the life-history and habits of the insect have already been studied to some extent, more especially by Carter, Imms, and Misra, our knowledge is still so incomplete that no general account can be other than superficial and fragmentary. The present account is based on earlier ones and on personal observation, while Appendix III indicates some of the more obvious gaps in our knowledge that ought to be filled up if we wish to obtain any effective control over the insect and the crop.

The lac insect, *Tachardia lacca*, belongs to the group of Coccidæ or scale-insects, so called from the scale or outer covering which is characteristic of most of them. This "scale" consists of various excretions and secretions, together with moulted-off skins, and it acts as a protective shield to the insect's body. In the case of the lac insect the "scale" is particularly thick and massive, and is composed of the amber-coloured resinous substance known as "lac", the raw material from which shellac is manufactured. Motionless under this amber shield the little purple insect lives most of its life, sucking through its delicate hair-like proboscis the juices of the plant to

* c.f. The descriptive term "millions" applied to the little West Indian fishes that are sometimes used to destroy mosquito-larvæ.

which it has fixed itself. Several varieties of the lac insect have been described, but as it is unknown how far the differences between them are of any importance from the practical point of view, we may for the time being consider them as one.

The life of the female insect is about six months, so there are two generations ("broods") in the year. The summer brood hatches and emerges as swarms of tiny larvæ* in the hot weather or early rains; it attains maturity during the cold weather, when its young ones likewise emerge from under the lac and constitute the winter brood, which will ultimately reproduce itself in the following hot weather. There are thus two periods of emergence or "swarming" of the young insect, and also two crops of lac, the summer *brood* emerging from the summer *crop* of lac, under which their dead mothers from the winter brood lie hidden, and the winter brood from the winter crop.

The swarming out of the newly hatched larvæ is a remarkable sight. It usually happens in the early morning, and most often, it is said, on a sunny day. Through holes in the crust of lac that has been produced by their mother, there emerge a great swarm of tiny slow-moving light crimson or mauve specks. These are the larvæ, and they move slowly about until they have found suitably tender shoots or twigs, one to two years old, on which they can establish themselves. Imms states that they can travel at least twelve feet without getting exhausted, but it is said that if they fail to find a suitable resting place on the first day they will rarely survive to find one at all. They take no food during this search and do not, as is often believed by the country-folk, return at night to take shelter in the resinous home from which they emerged.

The swarming period in any given locality generally lasts from three weeks to a month, but the majority of the larvæ usually appear in the first few days. It is noteworthy that the swarming period of lac insects growing on Kusum trees (which produce the best lac) is about a month later than that of lac insects on most other trees. During the whole period there is often a very heavy mortality from unsuitable climatic conditions, hereditary foes, and exhaustion, but a larva that succeeds in weathering these perils and finding a young

* Here the name "larvæ" is used to denote any stage of the insect up to the time when it begins to produce lac.

and succulent twig, at once proceeds to settle down. This it does by piercing the soft bark of the twig by means of an exceedingly slender beak or proboscis, finer than a hair, through which it sucks the juices of the twig.

Once fixed, it might be imagined that the insects had no further dangers to survive, except those due to enemies, but there is evidence to show that in the first month of their existence on the twig there is often a heavy mortality among them. The cause of this is unknown; it may be merely constitutional weakness due to poor stock, over-exhaustion in finding a fixing-spot, or failure to "strike oil" in sufficient abundance for proper nourishment. Whatever the cause, the mortality may amount (as shown by Misra) to 25 per cent. of the brood, and is thus by no means negligible. Besides this loss after fixation, large numbers of the newly-emerged larvæ frequently perish while still wandering in search of a fixing-spot. They are then very susceptible to unfavourable climatic conditions, frost, dry dusty winds, hail or heavy rain, while they are also carried by wind away from their food-plant and may in this way be removed to considerable distances. It is thus evident that the time of swarming, fixation, and the first week or two after fixation, is a critical period of the insect's life; and that the conditions that prevail during this period will largely influence the welfare of the brood and therefore its output of lac.

The female larvæ that effect a satisfactory fixation are fixed for life. They at once begin, by some process which is not understood, to produce the waxy and resinous matter known as lac, as well as a sugary excrement or "honey-dew". This latter drips from the colonies on the twigs above down on to the leaves below, covering them with a sugary glaze that affords nourishment to a dirty-looking black mould. This mould has been identified by Mr. E. J. Butler, Imperial Mycologist, as consisting of species of *Capnodium* and *Fumago*, and its presence is a characteristic and easily-recognized mark of lac-bearing trees. The lac itself is exuded, at least mainly, from various glands in the skin, and that produced during this first stage is small in amount and very transparent. The insect, however, now proceeds to moult, *i.e.*, cast its skin, and in doing so loses its legs and all power of locomotion. It now becomes a pear-shaped sac; where the stalk of the pear would be is an indefinite head and the delicate proboscis, and at the other end is a small spine and three

rather conspicuous pimples or processes. At the apex of two of these are breathing-holes (spiracles) leading to internal breathing-tubes (tracheæ), while the third bears the opening of the anus; here also is the genital opening, and it is obviously important that all these holes should be kept open and not blocked up by lac. We find that as the insect's coating of lac gradually thickens, these holes are not as might be expected obliterated, but remain open; and that from them protrude delicate snow-white filaments of a waxy substance whose presence may somehow prevent the resinous lac from gradually filling up these three important apertures. With good healthy stock this waxy fluff is so abundant that the lac looks almost white all over, and its amount gives a rough indication of the condition and general vitality of the brood. At the same time there is no reason to suppose that the destruction of these filaments (*e.g.*, by ants running over them) results in any appreciable damage to the insect beneath though the reverse has been stated. They are not (as has also been asserted) continuations of the tracheæ, and are probably no more vital structures than is, for example, our own hair.

The females of the summer brood become sexually mature in about six or eight weeks, and those of the winter brood in about three to four months. They have then a fairly thick covering of lac, and are ready for the males who have been developing alongside them.

The males have a different course of development to that of the females, and they are distinguishable from them in early life by the smaller size and different shape of their covering of lac, of which they produce much less than the females. They do not remain for their whole lives imbedded in the lac, but about the time when the females become ripe for pairing, generally August-September and March-April, they crawl out from their lac cells and reveal themselves as having not only legs but often (in males of the winter brood) wings as well. The males of the summer brood are stated to be always wingless.

Having safely emerged from the lac, the males crawl or (if winged) fly about and proceed to fertilize the females that they find, the long copulatory organ of the male reaching the female through the anal aperture in the lac.

This emergence of males, which may be spread over a month or more, is another critical period in the life of the brood. Not only

are the males delicate creatures who easily succumb to adverse conditions of weather and the attacks of predaceous insects, but the females only produce their full crop of lac after they have been fertilized. If unfertilized they produce but little, and probably die early and childless, though perhaps the possibility of parthenogenetic production cannot yet be altogether excluded.

After performing their proper function the males die off. The females, now nearly a sixteenth of an inch long, begin to secrete lac at a greater rate, presumably because they are taking more food to supply the needs of the very large family of young ones developing in their ovaries. Perhaps about a month after being fertilized the female dies; the eggs, or young, emerge from her body, which collapses into a mere sac, and seems by its contraction to leave a vacant space in the lac which shows as an "orange spot": after sheltering for a short time (a week?) under the lac, at a suitable opportunity the little swarm of tiny mauve dots emerges on the outer world, to wander in search of fresh succulent shoots and fix themselves as already described.

The details of the life-history that we have here briefly sketched cannot be filled in, as they are still for the most part unknown, but enough has been said to enable us to pick out a few points which will evidently have an important influence on the crop of lac produced by a given brood.

These are—

- (1) The amount and quality of food obtainable from the plant on which the insects are fixed, dependent on the nature and habit of the plant, conditions of soil, weather, etc.
- (2) The vitality and hardiness of the strain or variety of insect engaged in the production, and its general efficiency as a producer of lac from the juice of the particular plant on which it is fixed.
- (3) Weather conditions, *e.g.*, presence or absence of hot drying winds, dust, frost, hail, heavy rain, at the time of swarming and fixation and at the time when the males are emerging. The general influence of climatic factors on the welfare, and therefore the distribution of lac insects.

- (4) Prevalence of natural enemies of the insect or the host-plant; including various predators and parasitic animals, human thieves, and fungal or bacterial diseases.

Unfortunately, very little is accurately known about any one of these four points. With regard to (1) and (2) our ignorance at present is practically complete. We do not know what substances in the plant the lac insect really feeds on, or what condition of the plant favours the production of these substances; nor have we any clear ideas as to the characteristics of different varieties of the lac insect and their relative efficiency as lac-producers. It is known that lac itself, including the lac-wax and dye that are also produced, is a complex substance made up of at least half a dozen different compounds; but of the physiological processes whereby it is made and secreted by the insect we are entirely ignorant.

As to point number three (weather and climate) we know that strong and dusty winds, frost, hail and heavy rain are all likely to cause serious loss at the critical periods of larval and male emergence; but as regards what may be called climatic distribution we have no definite or precise knowledge. That is to say, given an acquaintance with the meteorological data relating to the temperature, rainfall, and humidity of any particular place, we cannot say definitely whether that place is climatically suited to the lac insect or not.

With few exceptions, insects are affected by climate far more than we are, and are unable to live a healthy life, or even live at all, outside their own particular limits of temperature and humidity. These limits thus decide the climatic suitability, or otherwise, of any geographical area for the cultivation of any given kind of insect; and in a case like that of the lac insect, where extension of cultivation is desirable, waste of money or energy may be avoided if the limits, and the optimum conditions which lie somewhere between them, are definitely ascertained.

All that we know at present is that areas where lac is at present most abundantly grown, namely, Chota Nagpur, Orissa, and the east of the Central Provinces, are generally over 1,000 feet above sea-level and enjoy a fairly temperate climate. The annual rainfall is from 50 to 60 inches, and occasional showers are secured during the winter and summer months, outside the regular rainy season. The general humidity is low. Frost, although fairly common in parts

of the tract such as Damoh, can be avoided on the hill slopes, and hail, heavy tropical rains and dry hot winds are uncommon.

Point number four, relating to the enemies of lac, is the only one where a reasonable amount of accurate information is already available, and we owe this chiefly to the work of Imms, Chatterjee, and Misra. These observers are unanimous in attaching serious importance to the destruction of lac insects by natural enemies and parasites, and no one who has raised lac under observation is likely to disagree with them. Useful work has been done in identifying some of the more important parasites of the lac insect, but comparatively little is known regarding their habits, life-histories and distribution, or their relative destructiveness and the best means of combating them.

These four points are considered in a rather broader and more general sense in Appendix III on "Research", but it is as well that we should realize at the outset how very patchy and superficial our knowledge is as regards what may be called the biological side of the study of lac, that is to say, the side which deals with the two living organisms concerned, the lac-insect and its food-plant; the nature of the relations that exist between the insect and the plant, or between different varieties of insect and plant, the nature of the substances from which the insect elaborates its lac, the physiological process by which it performs this remarkable operation, the effect of climatic and other conditions on the plant, insect, and lac-production, and the methods of protecting either plant or insect from the many enemies that beset and injure them.

Although, as we have said, the information at our disposal on most points connected with the insects and "host"-trees they feed on is fragmentary, and a good deal of it untrustworthy, it may be permissible to draw attention to a few miscellaneous matters that are of biological and practical interest.

One may say that the produce of the lac-insect is as follows:—

- (1) Lac, consisting of a complex of *resinous substances* and waxes, the amount of waxy matter being less than 10 per cent. There is also a little colouring matter present.
- (2) *Lac-dye*, consisting of at least two dye-stuffs, and almost entirely concentrated in the body of the insect and its eggs or young.

- (3) "Honey-dew", the insect's sugary excrement ; of no commercial value.

These substances are all manufactured by the insect from the material it sucks up from its "host"-plant. The honey-dew is excreted, the lac-dye accumulated in the body and in the eggs, while the various components of "lac" are apparently elaborated in special secretory glands and exude like sweat from various parts of the body, the yield being specially abundant from the female during the period of gestation.

On these processes—probably on all of them—the nature of the insect's food, or the kind of plant on which it is living, has an influence in the sense that the lac produced by the same strain of lac insect from different plants will not be quite the same quality. It has indeed been thought that the part played by the insect is practically that of a strainer or filter—that the plant-juice is sucked up, some of its constituents absorbed and digested by the insect, and the rest excreted in the form of lac.

In that case the composition of lac from a given plant will depend directly on the composition of its "juice", and will probably vary a good deal with different plants. Personally we think there is no doubt that the other view is correct ; that the insect "manufactures" the lac in its own body from raw materials that it gets from the plant-juice. The composition of the lac from a given plant will then depend only indirectly on the composition of its juice, and (as seems to be the case) will generally remain fairly constant whatever the plant from which its raw materials were derived. Whichever view may be the correct one, there is certainly some difference (especially in colour, to which the trade attaches much importance) in the lac from different plants, and moreover the insect apparently tends in time to develop different physiological characteristics according to the plant on which it is kept.

A list of the principal food-plants is given in Chapter II. The most important are :—

- (1) The Kusum (*Schleichera trijuga*).
- (2) The Ber (*Zizyphus Jujuba*).
- (3) The Ghont (*Zizyphus xylopyrus*).
- (4) The Palas or Dhak (*Butea frondosa*).

Kusum lac is specially light and clear in colour, and is more highly valued than that from any other tree. Moreover, it is generally accepted that brood from the Kusum tree will thrive on any other lac-bearing tree to which it may be transferred; but that the reverse is not the case, as insects from other trees will not live on transfer to the Kusum tree. An explanation generally current is that the Kusum tree has a harder and thicker bark than other trees and that the Kusum insect has thus developed a stronger and longer proboscis which is able easily to penetrate softer and thinner barks; whereas the proboscis of insects from other trees is unable to penetrate the Kusum bark. It is in the writers' opinion more probable that the failure of insects from other plants to live on Kusum, if indeed they do fail, is due to physiological causes rather than to any structural weakness.

In this connection it is interesting to find that when Kusum brood is transferred to the Palas tree, the first crop is known as "Bastard lac", and it is said that its properties are intermediate between those of Kusum and Palas lac, while subsequent crops approximate more and more to the Palas variety.

There are various statements and beliefs to be found regarding the relative facility with which different plants are colonizable by the lac insect, but they seem never to have been tested by any actual experimental enquiry, and there is reason to believe that at least some of them are mistaken. Thus lac-bearing trees still require to be classified in order of their suitability or unsuitability for promiscuous propagation, if any definite order does actually exist, so that the brood from any tree on the list might be successfully transferred to any other tree classified below it, though perhaps not to any tree classified above it. Of the four trees mentioned above, the correct order on this principle is stated to be :—

- (1) Kusum.
- (2) Ber.
- (3) Ghont.
- (4) Palas.

A further distinction, already referred to, between the Kusum and other trees considered as "hosts" for the lac insect, relates to the periods of swarming. On the Kusum tree the summer brood usually emerges during July-August and on other trees during June-July;

the winter brood on Kusum emerges during December-January, and on other trees during late October-December. There are, however, considerable local variations in these periods, some particulars of which have been recorded by Imms and Chatterjee. It is of great importance that the swarming periods should be carefully determined for each lac-growing area and for each important "host"-tree. Imms and Chatterjee quote an exceptional case in which, in 1913, samples of stick-lac from the Kheri forest swarmed on February 22nd. A parallel instance was observed by Lindsay, when stick-lac that had been kept for some time in bags in the Rang Lal factory at Ranchi swarmed on exposure to the light. Observation in the laboratory indicates that at certain stages the swarming larvæ are "positively heliotropic"; in other words, they go towards the light, *e.g.* of a sunny morning, and it may thus be possible to delay the swarming of brood-lac by keeping it in a light-tight receptacle. This might under certain circumstances be of considerable practical value in connection with the collection, storage, and transport of brood-lac from one locality to another.

Vague statements have appeared to the effect that in Mysore and Burma there are lac insects which breed three times in a year instead of twice. Whether this is the case or not remains to be seen, but it is interesting to note that lac from *Shorea Talura* in Bangalore, which originated from a swarm in the latter part of December, swarmed on April 21st in the laboratory at Dehra Dun, a remarkably early date. This seems to be the most definite evidence as yet available as to the existence or otherwise of this tri-voltine breed; but the possibility of getting three crops instead of two is certainly of interest.

It is from every point of view desirable that a comparative study of the different varieties of lac insect from different areas should be made in order to arrive at some definite knowledge of their hardiness, adaptability to particular host-plants, and lac-producing efficiency. The fact that we are still unable to say whether there is, or is not, a tri-voltine variety of an insect of such great commercial importance is an indication of the extent to which its general study has been neglected.

There is one particular side of its study—the physiological side—which has also been entirely neglected, perhaps on account

of its difficulty, although it is of very great practical importance. This question of physiology—namely, what is the nature of the transformation that goes on inside the insect's body—lies at the root of the whole matter. When we have found out how the insect makes its lac and what raw materials it uses, we may begin to stimulate its production and control the quality of its produce; but until the physiological question is tackled, no confident advance in these and many other directions is possible, and this is the point on which attention should primarily be focussed in the event of biological research on lac being undertaken.

Another biological enquiry of much importance is that relating to the enemies, parasites and diseases of the lac insect and its food plants. In the case of the insect, there is a good foundation for this study in the work of Imms and Chatterjee, who have described some of its more important enemies. The most destructive of these are the caterpillars of three or four species of small moths of the genera *Eublemma*, *Hypatina* and *Holococera*, and a few small Hymenopterous (Chalcid) parasites. The Chalcid larvæ probably consume the bodies of the living lac insect, while the caterpillars of the moths (*Eublemma amabilis* being the most notorious) apparently consume both lac and insect, riddling the lac with their web-lined tunnels. Some of the Chalcids may also quite possibly be "hyper-parasites" of the caterpillars, and therefore beneficial.

Among those qualified to judge there is complete agreement as to the seriousness of the loss occasioned by these insects, though its actual magnitude cannot yet be estimated. Imms, who has devoted considerable attention to their study, believes the loss to be very large, and urges the importance of a more detailed investigation with the object of checking their ravages. He suggests a scheme for determining whether the lac insect is the only insect that they victimize, or whether they have other hosts. The point is of prime importance in considering preventive measures, and an abstract of the scheme is given in the Appendix on "Research."

Ants are believed by some to do serious damage to lac, and they are very frequently seen running about on it in a manner which looks suspiciously predaceous. It is probable, however, that they are merely licking up the valueless "honey-dew", to which they are passionately attached; many other *Coccidæ* besides the lac insect are attended

by ants for the sake of their honey-dew, and there is no reason to suppose that ants are really responsible for any appreciable amount of damage. Imms gives a list of eleven species of ants that are often found associated with lac insects, but thinks it unlikely that they are of any importance as enemies.

At present no fungal or bacterial disease is known to attack the lac insect, a fact which encourages the hope that their future intensive cultivation under more completely domestic conditions, as in the case of the silk-worm, may not be a matter of exceptional risk or difficulty. The enemies and diseases of the many food-plants of lac are too numerous to be mentioned here, and no one of them can be considered of sufficient general importance to merit detailed treatment in a report of this kind. The last and perhaps at present the most important enemy of all, the human thief, hardly comes within the normal scope of this chapter, but it may be suggested that intensive cultivation of the insect under more nearly "domestic" conditions would probably be the simplest way of checking loss from theft.

CHAPTER II.

THE HOST-TREES OF THE LAC INSECT.

This subject has up to the present time received practically no attention whatever. The authorities do not discuss it, or else dismiss it in a very few lines, although it is of the highest importance if lac is ever to be cultivated on scientific principles. If the host is to receive special treatment preparatory to inoculation with lac, or remedial treatment to hasten its recovery from the after-effects, it is obvious that the precise relations between the insect and the tree must be carefully studied.

The relations between the lac insect and its host.

If one compares a tree bearing lac with an uninfected neighbour of the same species, the first point noticed is that the former has lost considerably in vigour. The vegetative growth is poor, the canopy is small, the leaves are much fewer, while flowers and fruit are often absent; the new shoots are weak and thin and the tree generally presents a very unhealthy appearance. In fact, with certain species of tree, *e.g.*, Ghont, it has been noticed that repeated and heavy inoculations with lac eventually kill the tree altogether. The natural deduction from the above facts is that infection with lac is fraught with consequences injurious to the health of the tree. It would seem, therefore, that one of the aims of cultivation should be to maintain an equilibrium between the lac and the tree and not to over-infect or too frequently to infect the same host-tree, as this course will eventually destroy it. The only condition under which heavy infection is admissible is when the number of host-trees is sufficient to allow of a rotation for replacement or recovery and their regeneration is assured. This condition nowhere obtains at present in the main lac-growing areas.

Although the above theory, that lac is a disease of the host, is generally accepted as correct, Mr. S. Mahdihassan of Hyderabad (Deccan) has published a pamphlet in which he takes up an entirely different attitude. On this pamphlet Mr. F. M. Howlett has recorded the following opinion:—"Mr. Mahdihassan considers that the lac insect's normal function is a beneficent one, in that it thrives

only (or mainly) on plants more or less afflicted with "gummosis," a disease involving an abnormal growth of gum-producing bacteria in the tissues of the plant; the suctorial activities of the insect, by removing the gum and the bacteria that produce it, thus actually promote the welfare of the plant by reducing the disease.

"The more ordinary view, to which I confess I still adhere, is that a diseased condition of the plant is in no way essential to its successful colonization by lac insects, whose sensory, suctorial, digestive, and secretory apparatus has in the course of several million years become fitted to find, extract, and digestively deal with certain compounds that are normally present in the sap and cambial layer of many plants, the plants being, in the ordinary sense of the word, the insect's victims. If the larval lac insect finds itself on a branch (whose bark is not too thick to pierce) of any plant whose juice suits its digestion, it will, I believe, attack it, even though the plant itself may be perfectly healthy and vigorous. It is generally believed that if the number of lac insects on a tree be large, their combined attack may kill the tree, just as does that of any other ordinary "pest". There is in short no reason as yet to attribute to the lac insect any beneficent rôle, or to doubt that its attack tends to hurt rather than help its "host" or victim. In other words, from the point of view of the tree the lac insect is a pest and not a physician, and no definite symbiotic tendency has yet been demonstrated.

"In this connection it is also appropriate to point out that our comprehensive ignorance of the insect's physiology does not justify Mr. Mahdihassan's assumption that lac is produced from the water-soluble gums present in the plant. Lac itself is far from being a simple substance, but is a complex of some half a dozen by no means simple compounds, and at least some of these compounds may very probably be derived from fatty acids and essential oils or terpenes rather than from gum. Until therefore the digestive and secretory physiology of the insect has been investigated, it is unprofitable to make any positive statements as to the genesis of lac."

A fact which at first sight seems somewhat remarkable is that the lac insect is able to pass through two generations in a single growing season of the host; for it seems *a priori* unlikely that the peculiar conditions necessary for the welfare of an insect with so involved a life-history as the lac insect could recur at two different

periods in a single growing season of the host. The apparent explanation of this fact (though it has admittedly not been proved) is that in India most trees, if they have not two growing seasons in the year, have at any rate two periods in the growing season when their vegetative activity is much greater than usual. These periods are in the hot weather preceding the rainy season, and again in the autumn immediately after the rains. Most trees produce long shoots at both these periods and the flowering time is frequently at one or other of them. With a view to further consideration and enquiry it is here suggested that the period of intense lac production immediately following the impregnation of the female lac insect coincides with or is in some way dependent on the corresponding period of vegetative activity of the host; and that the reason why the winter brood takes so long to mature, and why a comparatively small amount of lac is produced before March, is that the host is then inactive and its branches contain very little sap before that month. Should this theory be found correct it will provide a simple explanation of the fact that in the autumn brood the male undergoes his metamorphosis in about one month while in the spring brood he takes $3\frac{1}{2}$ months; on the assumptions, firstly, that he is waiting for the period of vegetative activity on the part of the host so that the abundant supply of food required by the female during the first part of the period of gestation may be forthcoming, and secondly that lac production by the female is a measure of food absorption.

The lac insect appears to be able to sustain life for a time at least on almost any tree or shrub on which
The principal host-trees. it is placed, but it is only on a few that it can thrive well and reproduce itself. Very much smaller is the number of trees and shrubs on which the cultivation of lac is of real commercial importance. The following are the more important species :—

Name used in this note.	Systematic name.	Bihar and Orissa.	Central Provinces.	United Provinces.	Burma.	Assam.	Punjab.	Bombay.	Madras.
Palas	<i>Butea frondosa</i> , Roxb.	Paras, Faras.	Cheola, Dhak, Palas.	Dhak, Palas	Pauk	Lahokung...	Palas ...	Palas, Khakara.	Parasa, Moduga.
Kusum	<i>Schleichera trijuga</i> , Willd.	Kusum...	Kusum...	Kusum ...	Gyo	...	Kusumb, Samna.	Kusum, Peduman.	Pava.
Ber...	<i>Zizyphus Jujuba</i> , Lamk.	Kul, Kuli, Ber.	Ber, Ringa (Gond).	Ber ...	Z	...	Ber ...	Ber, Jangri (Sind).	Eladap, Regu.
Ghont	<i>Zizyphus xylophyra</i> , Willd.	...	Ghont, Ghatber.	Kathber, Bhander, Chitena.	...	...	...	Goti ...	Kuttai.
Pipal	<i>Ficus religiosa</i> , Linn.	Pipal ...	Pipal ...	Pipal ...	Nyaungbandi.	Borbar ...	Pipal ...	Pipur, Sind Pimpal.	Arasa.
Babul	<i>Acacia arabica</i> , Willd.	Babul ...	Babul ...	Babul ...	...	...	Kikar ...	Babar (Sind)	Tuna, Gobli.
Arhar	<i>Cajanus indicus</i> , Spreng.	Arhar, Rahar.	Arhar, Tur.	Arhar, Tuar.	Pesingon...	Mirimah, Garomah.	Arhar, Tohar.	Tura ...	Tuvarai.

The following are of less importance at present but are worthy of consideration and extended trial :—

Ficus spp. *infectoria*, *glomerata*, *Rumphii*, etc.
Albizzia *Lebbek* and other *Albizzia* species.
Acacia *Catechu* and other *Acacia* species.
Butea *superba*.
Dalbergia *latifolia*, *paniculata* and other species.
Mangifera *indica*, the mango tree.
Ougeinia *dalbergioides*.
Pithecolobium species.
Shorea spp. *Talura*, *obtusa*.
Tamarix *gallica*.
Prosopis *spicigera*.
Spatholobus *Roxburghii*.
Pentacme *suavis*.
Dipterocarpus *tuberculatus*.

Stebbing gives a long list of other trees on which lac will grow, but they are of little commercial interest.

Palas.—The *Palas* grows wild over the greater part of the plains of India and is usually gregarious on good soils. It occurs in typical mixed forest on poor soils but is more a tree of the open country and scrub jungle of which it is frequently the principal species. It is a moderate-sized deciduous tree, frequently with a crooked irregular stem. A red astringent gum exudes when incisions are made in the bark. The leaves are in threes, but shoots with single leaves may sometimes be found. The flowers, which appear in late March and April, are red (occasionally yellow), and the tree is often popularly known as “flame of the forest”. The fruit is a bean, ripening in the hot weather. The leaves follow the flowers and fall in February, so that the tree is bare from February to April. The wood is used little for timber, but frequently for fuel, although the tree is now generally conserved for the cultivation of lac. It is very easy to propagate from seed and will grow rapidly to 18 inches girth and 20 feet high in 15 years (10 years if irrigated). It coppices very well, is frost-hardy and drought-hardy and rarely browsed even by goats. The formation of regular *Palas* plantations, though easy, is not recommended, as *Ber* is equally easy to establish and will give

better results. Palas responds well to pruning and repeated pruning does not appear to affect materially its power of throwing out pollard shoots.

Kusum.—A large deciduous tree found in the sub-Himalayan tract from the Sutlej eastwards, in the southern C. P., Chota Nagpur, Orissa and Burma. It is found elsewhere, but is not common. It is never gregarious, but occurs scattered in high forest and occasionally in groups of a few trees. It seems to prefer a high altitude and to grow best at about 2,000 feet, and is frequently found by the side of rivers and nalas, but cannot stand water-logging and, once established, is drought-hardy. In dry deciduous forests it stands out as a conspicuous object during the hot weather months on account of its fresh green foliage. Kusum is decidedly slow in growth, coppices poorly and pollards less vigorously than other lac-growing species. The old leaves are shed in February and the new appear in March-April, purple at first, changing to a fresh light green. The flowers follow the leaves immediately and the fruit ripens in the hot season. Thus in habit it closely resembles *Shorea robusta* (Sal) with which it is frequently found mixed. It may be raised easily from seed or cuttings, but in early years is very slow in growth. In general appearance it closely resembles *Bassia latifolia* (Mohwa), though it is readily distinguished by its lighter bark and characteristic leaf formation—no terminal leaflet, but generally three on each side.

Kusum produces a finer quality and larger individual crop than any other known lac-bearing species, but its solitary habit and preference for heavy jungle increase the cost of cultivation and discourage its more extensive use as a lac host. Lac cultivators profess to be able to distinguish several varieties. In Raipur there are said to be two varieties, one with a small curly leaf and the other with large leaves. Only as a last resort will the cultivator infect the curly leaved variety; his explanation is that the sap is acrid and that the insects may die on attachment. In other places cultivators will distinguish as many as four varieties, but always by leaf variations. It is probably merely a question of locality, but requires investigation.

Kusum is affected very strongly by the attacks of the lac insect and requires several years to recover its vitality, so that at least a three years' rotation is necessary.

Wherever Kusum exists in sufficient quantities its infection with lac is recommended, but on account of its slow growth private

individuals will rarely care to undertake the formation of plantations. Kusum sown fifteen years ago along nala banks in Raipur are still straggling bushes, unfit for lac cultivation. The experiment is, however, hardly conclusive as, once sown, the trees received no further attention. Kusum wood is hard, with close and twisted grain, heavy, tough and strong, and its heart-wood is reddish. The fruit is of some commercial importance as it yields a macassar oil.

Ber.—*Ber* is the wild (but also cultivated) edible plum tree found almost anywhere in India. It is a medium-sized evergreen tree, grows well in poor soils, but much better in good manured soils. Its branches have a tendency to droop and are covered with thorns. The leaves are oval and about 1"—1½" long; the young foliage appears in March-April while the old leaves are dropping. The flowering period varies, but in the lac area generally follows the new leaves immediately. The fruit ripens in December-January. It has been very widely cultivated in the past in gardens and around homesteads for the sake of its fruit, but in lac-growing districts such as Manbhum and the Sonthal Parganas, the conservation for fruit has almost entirely given place to the cultivation of lac. If it gets plenty of animal manure its growth is vigorous and it gives good crops of lac which can be cultivated on a twelve months' rotation.

The propagation of *Ber* from seed is easy, growth in favourable localities is rapid and the tree is fit to inoculate with lac in five to ten years' time. It coppices well and according to local traditions must be coppiced in early youth as seedling trees will not bear lac. There is, however, no scientific confirmation of this theory.

On account of the ease with which this tree can be propagated, the good quality of its lac crops and its alternative value as a fruit producer, it is very popular as a lac host. It is gradually replacing *Palas* and is the tree to be recommended to anyone desirous of raising plantations with the object of cultivating lac.

Ghont.—This species, which appears to replace *Ber* in rocky hill tracts, is to be found all over India. Usually scattered in mixed types of forest, it appears to reach its optimum in a small area including the whole of Damoh district (C. P.) and adjoining areas in Saugor, Jubbulpore and Narsingpur districts, and in several of the Central India States. Here it is practically gregarious. It closely resembles *Ber* in habit, but is straggling in growth and inclined to

be less thorny. It appears to have developed on parallel lines with Ber but has more xerophytic adaptations. It seems to prefer a well-drained rocky soil and has been seen growing with some vigour out of sheet rock.

It coppices and pollards well and is a very suitable host for lac wherever it exists naturally; but it appears to feel the effects of lac cultivation somewhat severely, and therefore care must be taken, until knowledge is more definite, not to over-infect it. It is probable that a two years' rotation will be found suitable for lac cultivation.

Pipal.—Pipal is a large glabrous tree, indigenous to the sub-Himalayan tract and to the Pegu Yoma. It is sacred to both Hindus and Buddhists and is therefore cultivated throughout India; it is commonly found growing in the interstices of masonry work on which it has a destructive effect. It can be raised from seed or cuttings and is of rapid growth. It is leafless for a short period in early summer, and usually bears fruit in the hot weather with occasionally (in the C. P.) a second crop in October-November.

The lac produced is of good colour but very poor quality and there is considerable religious prejudice among Hindus against the cultivation of lac on it, so that its use as a lac host on a commercial scale can hardly be recommended.

Babul.—The Babul is a moderate-sized tree cultivated throughout India, indigenous to Sind and the northern Deccan, gregarious in habit, evergreen, fast-growing. Its foliage first appears in the hot weather, and both foliage and pods are excellent fodder. A gum exudes from incisions made in the bark. Information as to the growth of this tree in the Deccan is summarized by Rao Bahadur S. Srinivasalu Nayadu in a paper read at the Nagpur Forest Conference in 1908. It flowers from July onwards and the fruit ripens in February. The seed has a hard testa or outer covering and germinates with difficulty unless specially prepared. The best results are obtained from the seed rejected by goats fed on the pods; it is then easy to propagate and in Berar grows to 12 or 15 feet in 10 years. It coppices badly.

Babul can boast a very large number of varieties. In Berar three are recognized and the fact that Babul brood lac cannot be propagated in other parts of India than Sind is probably due to the existence there of local varieties of Babul as well as possibly to local

varieties of the lac insect and to special climatic conditions. This, however, requires investigation.

Arhar.—Arhar is a field crop cultivated widely throughout India. Recently a field of Arhar plentifully infected with lac was seen in the Palamau district not far from Daltonganj. The brood had been taken from neighbouring Palas trees. The cultivator estimated that the lac crop would be ready to collect shortly before the Arhar itself was finally cut and harvested. Only in Assam, however, does Arhar live for a sufficiently long period to allow of its infection on a commercial scale with lac. There it is grown in freshly-burnt (or "jhumed") jungle soil, and survives long enough to bear two crops of lac. Infection is carried on from one Arhar crop to another. The possibility of introducing a longer-lived variety of Arhar, as a lac host, in India proper, would undoubtedly be worth investigation. Although the quality of the lac is not particularly good, the yield is plentiful and the incrustations are thick and well-developed.

CHAPTER III.

DISTRIBUTION.

Tachardia lacca is found distributed widely throughout India and extends into the adjacent countries on its eastern and north-eastern borders. It occurs in Bihar and Orissa, Bengal, Assam, Bhutan, Thibet, Nepal, the United Provinces, the Punjab, Bombay (including Sind), Central India, the Central Provinces and Berar, Hyderabad (Deccan), Mysore, Madras, Travancore, Burma, China, French Indo-China, Siam and the Straits Settlements. Its general distribution is therefore wide, but it is only grown on a commercially important scale in a few rather restricted areas.

The main area includes the whole of Chota Nagpur, Orissa, the north-eastern half of the Central Provinces including all the Chattisgarh Feudatory States, Bundelkhand and Baghelkhand; it extends into parts of the Bankura, Birbhum, Murshidabad and Malda districts of Bengal and into that part of the Mirzapur district (United Provinces) which lies south of the Sone river. The bulk of the world's lac is grown within this area. The other important areas are :—

- (1) *Sind*.—A narrow strip on both sides of the Indus in Hyderabad and Karachi districts.
- (2) *The Punjab*.—The Una Tahsil of Hoshiarpur district.
- (3) *Assam*.—The Khasi and Jaintia Hills, the Garo Hills, Kamrup and Nowgong districts, with extensions into Thibet.
- (4) *Burma*.—The Arakan Yomas, many districts of Upper Burma, the Northern and Southern Shan States and Karenni. This area extends into Siam, French Indo-China and China.

The following figures show the relative importance of these areas by outturn :—

Area.	Average total annual crop in maunds.	Percentage of total outturn.
	Mds.	
Main area	1,003,500	86.6
Sind	26,000	2.2
The Punjab	33,000	2.9
Assam	65,000	3.0
Burma, etc.... ..	62,000	5.3
Total	1,159,500	100.0

The Burma figures include an average of 7,000 maunds annually from French Indo-China and 16,000 from Siam, both of which are actually exported to France, and 9,000 from the Straits Settlements, usually exported to India.

The commercial importance of the subsidiary areas is even less than the above figures show, as all the high grade lacs are grown in the main area. The lac from Assam and Burma is hardly fit for the manufacture of even the low grades of Orange shellac and is commonly used for Garnet lac. Sind lac is quite good enough for TN and Punjab lac for better grades. There seems to be some indication that the further one goes from the main area, the worse is the quality of the lac.

An attempt has been made by means of the map attached to this report, to show the distribution of lac in the districts and Native States of the main area of production. There is no pretension that this map is accurate in detail. No attempt has been made to show the relative intensity of cultivation but this may well be judged by the occurrence of the large and small markets. The principal species of host-trees are indicated, together with the markets and manufacturing centres. Further details of distribution will be found in the local notes at the end of the report.

From the above account it is clear that India has a virtual monopoly of lac. Attempts have been made to transfer brood from India to Japan and parts of Africa; but, it is believed, with no success.

From the point of view of India it would be a mistake to encourage any repetition of these attempts as success might endanger an industry which now gives employment to thousands of regular workmen in this country and increases the earnings of hundreds of thousands of the poorer cultivators. India is more than capable of supplying all the world's shellac requirements for many years to come, and the extension of the industry, called for by the present strength of the foreign demand, may well take place on an adequate scale within her own borders. The boom in shellac during 1919-20 has aroused interest in lac throughout India and the result seems likely to be a considerable extension of cultivators. Later chapters show that none of the districts which now produce the largest quantities of lac are, in any sense of the term, intensively cultivated. Where Government action is taken to increase the supply, its object will be more easily fulfilled by systematising and intensifying cultivation in areas where success is assured, than in attempting to extend it to areas where it is not already grown commercially.

In Chapter I the climatic factors which influence the distribution of the lac insect have already been discussed. From the commercial point of view one other factor is of supreme importance, namely the quality and extent of communications, and in particular railways. A glance at the map of the main area shows that the area is wholly situated within the districts served by the Bengal-Nagpur and East Indian Railways, south of the Jumna and Ganges.

The lac markets are mostly situated on railways and the proximity of railways has thus a very stimulating effect on production. An excellent example is afforded by the Chattisgarh Feudatory States. The States producing the largest quantities of stick-lac are Korea, Raigarh and Kanker. These are small States and the only reason for their large production is their proximity to the markets at Pendra, Raigarh and Dhamtari, respectively. Conversely Orissa and Bastar, lying between the two B. N. R. main lines, form without exception the largest area in India unserved by railways; and, except for the Rajputana desert, the Chota Nagpur-Surguja area lying between the B. N. R. line and the E. I. R. Grand Chord is the next largest. Both these tracts are of the greatest importance, not only because they form part of the main lac area, but further because they contain large numbers of Kusum trees, hitherto entirely neglected. The

opening up of these tracts by means of railways will have an immediate effect on stick-lac production. The only project which seems up to the present to have taken definite form is the Raipur-Vizianagram chord, which should result in the development of very important Kusum areas in Raipur, Patna and Kalahandi.

CHAPTER IV.

CULTIVATION.

There are two broods of lac annually and each gives a crop of stick-lac, one in the hot weather or early rains from the winter brood and one in the cold weather from the summer brood. Kusum lac, however, is of much finer colour and quality and somewhat later in maturing than that on other trees ; and hence its two crops have received separate names and are treated as separate crops by the trade. There are thus annually four crops of lac :—

Baisakhi or Batri	...	...	The summer crop from all species except Kusum.
Katki or Rangeen	...	...	The winter crop from all species except Kusum,
Jethwi	...	...	The summer crop from Kusum.
Kusmi, Nagoli or Aghani		...	The winter crop from Kusum.

Originally the terms Kusmi and Rangeen were used generically to denote both crops from the Kusum tree and both crops from other trees respectively, but they are now reserved for the winter crops only. The names Baisakhi, Katki, Jethwi and Aghani are derived from the Hindi names of the months in which the crops are collected, Baisakh (April-May), Katik (October-November), Jeth (May-June), Aghan (November-December). The name Rangeen is derived from Rang (colour) and is used because the Katki crop is usually dark coloured. The derivation of the words Batri and Nagoli is not clear.

The Baisakhi crop is usually bigger and better in quality than the Katki crop, but there are exceptions to this rule. The important exceptions occur in Bhandara and neighbouring districts in the south Central Provinces and in the Ghont area in Damoh and adjoining districts in the north of the Central Provinces. The reason for these exceptions is not clear. Nor is it known why the Kusmi crop, *i.e.*, the winter crop from the Kusum tree, is always better than the Jethwi or summer crop, while the reverse is usually the case with other trees. Peculiarities of climate, soil, host and labour conditions appear to be the likely causes, but information is insufficient even for speculation.

The crops from different localities vary considerably in quality and hence in value. The following is roughly the order of preference by crops :—

Kusmi and Jethwi.

The variation between best and worst is small in this case.

- I. Bastar, Kanker, Raipur and west Orissa.
- II. East Orissa.
- III. Ranchi and Manbhum.
- IV. Palamau.

Baisakhi.

- I. Manbhum and Ranchi.
- II. Palamau.
- III. The Sonthal Parganas, Murshidabad, Malda, south Central Provinces.
- IV. North Central Provinces, Central India, Sind.

Katki.

- I. Central Provinces.
- II. Chota Nagpur.
- III. Sind, Assam.
- IV. Burma.

The Baisakhi and Katki crops are principally grown on Palas and *Zizyphus* spp., the latter giving somewhat superior lac. Lac from the *Ficus* spp. is of good colour, but rapidly deteriorates when dried, and is poor in quality. Burma lac and Arhar lac grown in Assam, are poor in quality and dark in colour, though they are generally very fine large incrustations on the stick.

The lac crops are further differentiated according as they are collected before or after the swarming of the insect. This is an important distinction as the presence or absence of the insect means a higher or lower proportion of the lac-dye of which pure shellac must be free. The names used are *ari* for lac from which the insect has not swarmed and *phunki* or *phungi* for lac from which the insect has swarmed. *Phunki* lac, besides being almost free from colour, has dried considerably and contains a much higher percentage of resin than *ari* lac and is, for this reason also, preferred by manufacturers. A further nice distinction is made in some parts between *phunki* lac which has swarmed on the tree and in the godown, the former being called *sona phunki* and the latter *gada phunki*. The distinction is not

of much practical importance, though *sona phunki* may be expected to be freer of dye than *gada phunki*.

In its primitive stages the industry involved no artificial measures. Existing methods of cultivation. of cultivation and consisted merely in collecting what lac grew wild and trusting to Nature to arrange for subsequent crops. What actually happened was that some small quantity of lac was left on the trees; and by rapid reproduction in a few years' time, sufficient insects matured to give another fair-sized crop. This method is still common in Burma and in areas where lac occurs spasmodically, but is not now of sufficient importance to merit more than passing reference.

The modern method, common all over the lac-growing areas, is to leave untouched the upper one-sixth or one-third of the crop when the lac is harvested. Unfortunately, however, when the larvæ emerge on the upper branches, the lower branches are bare of all leaves and succulent shoots, which were broken off in collecting the bulk of the crop for the market; and, moreover, the vigour of the tree has been reduced by the recent crop. The result is that the emerging larvæ find few suitable places for attachment and the greater number die. At the next swarming season there will be, on the top one-third of the tree, a small but not a very healthy brood, as the tree will be lacking in vigour and the sap will be scanty and poor. The lower two-thirds of the tree will show a few sickly, thin, pollard shoots. This brood also, on emergence, will occupy any suitable spots on the top branches, but the majority will fall on or through the pollard shoots below, where only comparatively few will succeed in attaching themselves.

A better method is now practised in parts of Manbhum, Ranchi and other Chota Nagpur districts and is extending into the Central Provinces. It is more common on Ber trees growing round homesteads than in the forest. The greater part of the lac is cut *ari*, but a proportion of the trees, often one-tenth, is reserved for brood-lac, and when the larvæ are ready to emerge the lac is removed and attached to trees which were not infected during the previous season. This is an excellent method in theory, but is very rarely properly carried out. The maximum secretion of lac is not attained until about a month before the swarming period and the cultivator is tempted to collect as much as possible, as early as possible, with a view to shorten the labour of watching the trees and minimize the risk of theft; or else

to secure the top of the market before other cultivators unload. The result of this improvidence is that, when the swarming period comes round, he too often finds that he has neither the brood nor the money to buy it, and either leaves his trees uninfected or mortgages his future crop to a money-lender in order to secure funds for the purchase of fresh brood, which is always sold at exorbitant rates during this period. His trees remain too lightly infected, and he may find the next crop hardly worth gathering and will have to leave it on the tree so that the subsequent crop may be big. Further, his choice of trees for infection is not carefully or intelligently made, and the trees never receive any special pruning prior to inoculation, however desirable this may be. Finally, when prices are low, the brood will be allowed almost to die out and brood-lac may be practically unprocurable when prices rise again.

The Esociet Company (W. A. Fraymouth, Esq., F.C.S., Managing Director) of Maihar, C.I., a company which aims at developing the resources of the States of Central India, employs the following method. It has adopted what is really the first principle of lac cultivation, namely, that no lac should be removed from the forest until it has surrendered its swarm of larvæ. The principal lac-bearing tree in this area is the Ghont. As labour is not so difficult to obtain during the winter season as during the rains, the Esociet rely chiefly on the Katki or winter crop for their market crop of lac but take care not to collect the *phunki* lac until the requisite number of larvæ have swarmed to provide for the Baisakhi or summer crop. As soon as the summer brood shows signs of being ready to swarm, labourers are sent into the forest to cut off all the branches which carry lac. These are laid on other trees not yet infected, on which the larvæ are allowed to swarm. No other pruning is done. When the larvæ have swarmed the *phunki* lac is collected. The chief defect of this method, which is a great advance on those previously discussed, is lack of concentration. The whole area under cultivation has to be regularly guarded to prevent theft, and the collection of the *phunki* lac is rendered very difficult by the indiscriminate way in which it is scattered throughout the forest. The methods employed in the Damoh Government Forests are similar to the above and it is probable that both have the same origin as the Esociet Company leased the Damoh Forests in 1915-17.

On the face of it, the system seems sound, but the study of the life-history of the insect reveals its defects and suggests scope for improvement. The position is as follows: The female insects remain attached to the branches throughout their life-period of about six months. During this period, new succulent twigs have sprouted on the tips of the branches on which the insects have secreted lac. The natural instinct of the new brood is to pass over the mother lac from which they emerge and to progress towards the extremities of the branches in their search for the fresh young twigs. Branches and twigs cross and re-cross occasionally, and some larvæ use these natural bridges to find homes on other branches. But the greater number undoubtedly settle on the fresh shoots at the end of the parent branches; and these are, of course, destroyed when the parent branch is cut in collecting the cold weather *phunki* crop by the Damoh method. It is not argued that the entire crop is thereby destroyed; if so the lac industry would have died out in the Damoh Government Forests, whereas it is increasing. But it is an undoubted fact that the system does not make full use of the Katki crop for propagation; and it is partly for this reason (in addition to those already mentioned) that the Baisakhi crop cannot be used as a commercial crop. A possible alternative would be to break off the *phunki* lac from the twig, leaving the latter unscathed with the new brood on its extremities. But this procedure would require much delicacy of touch, would mean the loss of much good *phunki* lac left adhering to the tree, and would be absolutely impossible of practical execution in present labour conditions on any extensive scale.

Of the lac now grown, only about 2 per cent. comes from Government Forests and perhaps 5 per cent. from areas leased by large cultivators or contractors. The rest is entirely in the hands of uneducated villagers, cultivating a few trees each. The higher caste Hindus are prejudiced against the industry on the ground that it involves taking the life of the insect. Most of the *lactora* or lac-growing castes are aboriginal, but not all aboriginals will undertake lac cultivation. The wilder the districts, the stronger is this caste prejudice. While in the Manbhum, Murshidabad and Malda districts it has largely disappeared, it is still quite strong in parts of the Central Provinces, where only one or two of the many septs of Gonds will engage

in it. The same prejudices affect the manufacture and handling of shellac, but to nothing like the same extent. There is no doubt that, as the material profits to be made from lac cultivation are realized, the prejudice against it is gradually dying out.

A serious obstacle to the extension of lac cultivation is the risk of petty theft. When the price of clean stick-lac is a hundred rupees a maund and over, as it was in early 1920, there is every incentive to an unscrupulous passer-by to steal some lac-bearing twigs which can be hidden on his person and subsequently sold for a few rupees. Theft of lac when the crop is maturing is the commonest petty crime in the lac districts, and it is so prevalent that in some cases police reports of theft have been of material assistance in ascertaining the distribution of cultivation. Fear of theft is the principal reason why most lac is cut *ari* and as little as possible, or none at all, is retained for brood purposes. The crops mature a month before the larvæ emerge, and if the cultivator keeps his lac for brood he must watch it for an extra month for no definite gain that he can see and with every prospect of having it stolen. In the Damoh district of the Central Provinces, where lac is cultivated on a large scale by the Forest Department, special rules have had to be issued under section 41 of the Indian Forest Act to protect lac in transit; all such lac must be covered by a pass from the grower, which is exchanged for an official pass at the nearest Forest Revenue Station. These rules should have a deterrent effect by making theft more difficult, but will by no means obviate the necessity of watching the crops for at least three months before the larvæ swarm. With extended cultivation the only safeguards are constant patrol and effective supervision.

In view of the widely varying circumstances in which lac is cultivated, it is not easy to furnish a general estimate of the cost of production. The following particulars have been furnished by the Settlement Officer of Chota Nagpur and may be taken as typical. The rent charged by a zamindar will vary with the species of tree to be infected. The actual sum is usually not fixed until after inspection of the crop and varies with its quality, from one-half to three annas each in the case of Palas trees and from two to eight annas each in the case of Kusum trees, although higher rates up to one or even two rupees are

known to have been charged for large Kusum trees heavily infected with lac. If the lac crop should fail no charge is made, and quarter or half rents will be taken for poor crops.

The cost of brood-lac for infection will naturally vary with the condition of the market and the circumstances of the case. In normal years a bundle of brood-lac sufficient to infect four fresh trees would cost one rupee; in addition the cultivator frequently introduces each year a small quantity of fresh brood-lac, which he may obtain either by purchase or by transfer from other trees settled with him. Two annas for each tree is perhaps a fair estimate of the average annual cost of infection in normal times, although prices have risen during the recent boom.

Each cultivator can infect from eight to ten trees in a full working day and for this the cost may be taken at two annas. There is also the cost of guarding the lac during its development. This charge, like that immediately preceding, is difficult to work out as it represents not the market cost of labour, but the value to the labourer of employment during his spare time; it may be taken at Rs. 2 per mensem for each block of 100 trees. The collection of the lac and its rough cleaning by the removal of superfluous twigs, etc., represents a full day's work for each tree and this also may be taken at two annas.

The total cost of cultivating a good crop of 100 Palas trees may, therefore, be taken at :—

					Rs.	a.	p.
Rent, say	12	8 0
Brood-lac	12	8 0
Cost of applying brood-lac		1	4 0
Cost of guarding lac for 4 months		8	0 0
Cost of harvesting	12	8 0
The total cost is thus					...	46	12 0

Against this expenditure the raiyat may expect to get a return of say two seers or four pounds of clean or *biuli* lac from each tree; that is to say, from 100 trees 5 maunds, for which he will obtain during a normal year from a minimum of Rs. 10 to a maximum of Rs. 20 per maund. During years when prices are abnormally high he may of course be able to secure as much as Rs. 40 or even Rs. 60 per maund for the best qualities; and such windfalls are remembered and their effect lasts for a considerable time as a

stimulus to production. In an average year he cannot hope for a return of much over Rs. 15 a maund, giving him a fair profit on the whole transaction. He will also obtain a small return from the sale of the *phunki* lac from which the brood has swarmed at the time of infection.

The shellac market is one of the most unstable and prices frequently fluctuate between wide levels.

General.

The prices of stick-lac follow the shellac prices and in the past, often for several successive seasons, cultivation has barely repaid the labour expended on it. The cultivator is generally uneducated and improvident. When prices rise trees are stripped of lac, brood-lac becomes difficult to obtain, and, if obtainable at all, secures a high premium. In order to get brood-lac, the cultivator will involve himself with a money-lender, and as the latter seizes most of the profits, the cultivator again loses interest. Co-operation is an obvious remedy and with close supervision should have excellent results. An alternative remedy is for Government and the big landholders to take steps to ensure ample supplies of brood-lac against seasons when it is scarce.

CHAPTER V.

SUGGESTIONS FOR IMPROVED METHODS OF CULTIVATION.

Among the desiderata for scientific methods of cultivation are a thorough knowledge of the life-history and habits of the lac insect and its hosts and of the effects of climate and locality upon them, and effective safeguards against the attacks of enemies. Our present meagre knowledge on these subjects has been summarized in previous chapters of this report. There is no pretension that the following method of cultivation is the best. It is the result of personal observation of existing methods and attempts to avoid their defects. It has not yet been put to any practical test, and will probably require modification, perhaps considerable modifications, to meet the requirements of different localities with varying conditions.

The requisite climatic conditions have been described in Chapter I. Subject to these, the ideal area for cultivation is one in which as large a number as possible of well-developed and vigorous lac-bearing trees are available. Small and decrepit trees should be avoided as they are liable to be killed even by a single infection with lac. Old trees should be felled and their places taken by seedlings or coppice shoots.

The best lac is produced on the Kusum tree and, were other conditions equal, every one would grow Kusum lac. Kusum is, however, not a gregarious species; it is generally found scattered through forests and its cultivation is difficult. Palas is a common tree, frequently gregarious, especially in open grazing grounds near habitations. It is, therefore, often preferred. Ber is becoming more and more popular. Though not indigenous to all lac-growing districts, it has been widely planted for the sake of its fruit. Moreover it is a hardy tree and produces lac in quantity and of good colour and high quality. Ghont, where it occurs naturally, is to be strongly recommended, especially in Damoh and neighbouring districts where it grows almost gregariously over large areas of forest. Pipal and Banyan are not recommended. Though of good colour the lac is of poor quality; the trees are not gregarious and there is considerable

religious feeling among Hindus against their infection with lac. Babul is the most important tree in Sind, but lac has not been successfully cultivated on it in other parts of India. Arhar is successfully used as a host-plant for lac in Assam but its success in India proper remains to be established. The lac produced on Arhar in Assam forms a fine heavy incrustation; but unfortunately the colour is dark and the general quality poor. It is more suitable for the manufacture of garnet lac than of TN. In other localities with special conditions other species will be found suitable, *e.g.*, *Shorea Talura* in Mysore.

With lac so valuable a product, so tempting to thieves and

Rotation.

requiring a comparatively large labour supply for its propagation and collection, concentration must be the key-note to cultivation. A heavy lac crop, however, impairs the vitality of the trees and a definite rotation of coupes in a definite cropping series should be fixed with a view to giving them a period of rest. The terms cropping series and coupe are used for want of better, and will be clearly understood by all engaged in forest work. The cropping series will be the unit and its size should be such that it can be watched by one lac watcher or, where continual watching is required, by one series of reliefs. For convenience of control it will be found best to keep the cropping series in Government Forests fairly large, and gangs of watchers may be necessary. No series, however, should be so large that parts of it are more than a few miles from a central point of control.

The rotation will depend chiefly on the species of the host, modified by locality, soil and climate. No research work has been done to find the correct rotations, but the following are suggested. If experience shows them to be either too short or too long, there will be no difficulty in making the necessary alterations :—

Kusum ...	...	...	3 years	6 coupes.
Ber ...	...	...	1 year	2 coupes, if on good soil.
Ghont ...	...	...	2 years	4 coupes.
Palas ...	...	...	2 years	4 coupes, possibly 1½ years only.

This means that for Kusum, for example, the area will be divided into six half-yearly coupes and each coupe will bear a crop for

one-half year and rest for $2\frac{1}{2}$ years, when it will again be infected. On poor soils the one year rotation for Ber will probably have to be lengthened, though C. S. Misra (Pusa Bulletin No. 28, 1912, Cultivation of Lac in the plains of India) states that successive crops have been obtained from it at Pusa for six years. Ber is, however, usually found on good soils or near habitations where it gets manured and tends to be vigorous.

When operations begin, pruning will be necessary in order to provide the maximum number of young succulent shoots for the swarming larvæ.

Pruning.

The periods of pruning are those when the growth of the host-tree is at its minimum. Most trees cease to grow for a time during the winter, and in many places February is an excellent time for pruning in preparation for the subsequent summer brood in July. For the winter infection in October-November (December-January for Kusum) pruning in July and early August will probably interfere least with the growth of the tree. It may be found possible to prune in February for lac inoculation in the following winter, but this is a matter for experiment. Misra (loc. cit.) should be consulted by lac cultivators and much assistance has been taken from him in writing this chapter.

Sharp, heavy-bladed knives only should be used in all lac work. The axe should never be used as it does not give a clean cut, tends to strip the bark and frequently results in serious damage to the tree. It is very likely that a large-sized pair of rose-growers' pruning shears would be found useful in lac cultivation, specially the recently advertised patterns with a draw-cut. Vigorous trees should be lightly pruned, old and decrepit trees heavily pruned. If vigorous young trees are heavily pruned the resulting pollard shoots will be fewer than with light pruning, will present a much smaller area for the lac insect and may become rapidly suberised towards their base, and unfit for inoculation. Misra advises dressing all pruned stumps with coal-tar or cow-dung. This is advisable but will only be possible where an ample labour supply is assured.

During the first rotation almost every tree will have to be pruned. In subsequent rotations it is hoped that the removal of the lac-bearing twigs will be sufficient. In fact the criterion of a correct rotation should be that the trees in a coupe become, by recovery of their vigour,

automatically in a condition for re-infection as their turn comes round. Trees or parts of trees where infection fails will have to be re-pruned in the second rotation.

Before commencing to infect his trees, the cultivator must have ascertained correctly the times of emergence of the insect. These vary from district to district and with the species of the host, and the only way to discover them is by personal observation or by local enquiry. The swarming in any particular district is regular almost within a few days, but the winter swarm tends to be delayed by late rains and accelerated if the monsoon is short. Similarly a damp hot weather tends to delay the summer swarming.

About three weeks or a month before swarming the insect loses its white filaments and orange spots appear above each mother cell. At this time the mother insect ceases to feed and all her energies are taken up with the development of the coming brood. The appearance of the orange spots is a safe indication that she has reached this stage and will suffer no harm if her food supply is stopped. All the brood-lac required for purposes of propagation should now be gathered, care being taken to select only healthy and vigorous lac for this purpose. Any lac which appears to be full of predators should be rejected. The twigs should be cut into lengths of eight inches to one foot and stored until required in a moderate temperature and kept well ventilated. As the time of emergence approaches there is no need to store newly collected brood-lac, but it may be put out immediately on the trees prepared for inoculation. All twigs not bearing any lac should be cut off.

Several methods may be employed for infecting trees. The ideal is that which resembles natural conditions most, namely to wedge and tie the stick of brood-lac between two twigs to be infected, so that each of its two extremities touches a twig. The emerging larvæ can then walk directly from either end of the brood stick on to their new home. This method is, however, far too laborious for practical purposes. The commonest method is to tie several sticks of brood-lac loosely with straw to a branch of the tree immediately below the point from which a group of pollard shoots originates. The actual tying of the brood to the tree can frequently be dispensed with by placing the brood sticks in among the bases of a

number of pollard shoots. Misra recommends the use of small bamboo receptacles (costing 12 annas per hundred) fully described by him. These are filled with sticks of brood-lac and tied to the tree immediately below the points of infection. The advantage of the use of these receptacles is that they can be made and filled at a central depôt, are quickly put out on the trees and after infection can be rapidly collected. An important problem which can only be solved by practical experience is how to avoid over-infecting the trees and how to use, at each point of infection, the correct amount of brood-lac and no more. With cultivation on a small scale the brood can be removed when the trees are sufficiently infected, but in large scale work this is impossible and the amount of brood required can only be estimated.

As soon as the infection of the new coupe is satisfactorily completed, every bit of lac (now *phunki*) can be removed from the old coupe and sold; as also the lac fastened to the new coupe, when the brood has swarmed.

The work in a Kusum area during the first rotation will be as follows, the cropping series having been divided into six coupes numbered I, II, III, IV, V, VI :—

February 1920...	...	Prune all trees in Coupe I.
July 1920 ...	...	Collect brood-lac and infect trees in Coupe I.
August 1920 ...	...	Collect <i>phunki</i> brood-lac in Coupe I and prune trees in Coupe II.
Dec. 1920, Jan. 1921	...	Collect brood-lac from Coupe I and infect in Coupe II.
January 1921 ...	...	Completely remove all lac from Coupe I and collect the <i>phunki</i> lac in Coupe II.
February 1921...	...	Prune trees in Coupe III.
July 1921 ...	...	Collect brood-lac from Coupe II and infect in Coupe III.
August 1921 ...	...	Completely remove all lac from Coupe II and collect <i>phunki</i> lac in Coupe III and prune in Coupe IV.
Dec. 1921, Jan. 1922	...	Collect brood-lac from Coupe III and infect in Coupe IV ; completely remove all lac from Coupe III,

and so on.

As the lac cultivator will have to keep a careful watch against theft during the months late April, May, June, and again in late September, October, November, it is clear that lac cultivation is practically a whole-time employment with slack periods (where Kusum is the host) in March-April and again in September. Where other trees are hosts the slack periods will be rather earlier in the year.

Mr. C. A. Malcolm, Deputy Conservator of Forests, Saugor Division, has kindly supplied statistics

Costs.

showing the cost of lac cultivation on

Ghont trees in that division under the Damoh system. On these the following are based. A well-stocked area should contain at least 40 trees per acre. Assuming a coupe of 300 acres or 12,000 trees, two lac guards will be required to supervise the work and a quarter share of the services of an Overseer. Omitting all cost of brood-lac, which will be obtained from the previous coupe, the cost for one cropping series, taking an average of six months' work, is as follows. The Overseer draws Rs. 25 per mensem but can look after four series. Six months' pay is Rs. 150 of which Rs. 37-8-0 is debitable against each felling series. Two guards on Rs. 12 each for six months, Rs. 144. Each tree on an average will require infection in say 10 places. Coolies working in pairs and collecting their own brood can fix at least 150 bundles each and infect 15 trees daily or 400 during the season. The infection of a coupe of 300 acres will, therefore, employ 25 to 30 coolies for about one month. Collection of both *phunki* brood-lac and the lac from the previous coupe will take somewhat less time. Each tree will produce in a good season 3 to 5 seers of lac. Assuming 1 seer only as a moderate average the total yield will be 300 maunds.

Details of cost:—

	Rs.	a.	p.
Quarter services of one Overseer on Rs. 25 per mensem for 6 months	37	8	0
Two guards on Rs. 12 each for 6 months	144	0	0
Pruning 12,000 trees, say	750	0	0
Infecting 12,000 trees, say	300	0	0
Collection, dry cleaning, etc., of 300 maunds at Rs. 4... ..	1,200	0	0
300 bags	225	0	0
Depôt charges	100	0	0
Carting at annas 8 per maund	150	0	0
Sundries	93	8	0
Total	3,000	0	0

or Rs. 10 per maund.

During 1912 the Calcutta price of *biuli* lac varied from Rs. 11-12-0 to Rs. 15 per maund and during 1913 from Rs. 15 to Rs. 26. Prices secured during 1918 to 1920 have, of course, been much higher. It is clear, therefore, that the profits on the departmental

cultivation of lac should be high, but it is also clear that the labour required for intensive cultivation on a large scale will be considerable. In the example taken above, no debit has been shown for capital charges such as buildings, which will not be heavy, or for rent, which it is impossible to estimate.

The enemies of lac have already been dealt with in Chapter I.

General.

It is impossible to suggest any safeguards against predators and parasites until more is known of their life-histories and habits. In the meantime the use of clean brood-lac as free as possible from parasites and predators is to be encouraged. Imms and Chatterjee found that lac from the Hoshangabad district of the C. P. was cleaner than any other. Enquiries for brood should be made at Itarsi and Bankheri. The Divisional Forest Officer might be able to supply some, but most of the lac in this district is grown outside Government Forests.

Labour conditions are an important consideration and have already been described. The selected site must be one in which the local labour supply is plentiful and not predisposed against the cultivation of lac. The remedy is to offer good wages and to show that up-to-date methods of cultivation, and particularly the collection of *phunki* lac only for the market, tend to foster and not to destroy the insect. When it is demonstrated that scientific methods ensure better results and bigger profits, the cultivator will not be slow in adopting them. Meanwhile the method described above, of reserving a few trees for brood purposes, is extending and will be found an excellent stepping-stone towards the adoption of more scientific methods when they are known.

All the authorities who have written on the subject have suggested improved methods of lac cultivation, but it

The application of improved methods of cultivation.

is not so easy to give practical effect to such methods or to ensure their general adoption. The Forest Department is probably the best adapted for the work, particularly in the Central Provinces where the Forest staff is in close touch with the cultivator throughout the greater part of the Province. There are certain areas, however, especially in the Chhattisgarh Division, where there is little or no Government Forest and where in consequence special arrangements will have to be made. The other important lac-producing province, Bihar and Orissa, has

very little Government Forest and only a small Forest staff. Where there is Forest staff, as in Palamau, the Sonthal Parganas, Singhbhum and Sambalpur, the work can be carried out departmentally, but in the very important lac districts of Manbhum, Ranchi, Hazaribagh and Gaya, there is practically no Forest staff. In these districts, as in the Chattisgarh Division of the Central Provinces, special arrangements will be necessary. The Central India States and the Feudatory States of Orissa and the Central Provinces will doubtless, in their own interest, adopt similar measures within their respective territories.

The work that is required may be divided into two heads, the distribution of brood and the demonstration of improved methods. Though different in purpose, these two objects may be effected by a single means. Several writers have already suggested the establishment of what may be termed Lac Brood Farms, namely areas containing lac-growing trees managed by Government for brood and demonstration purposes. If they are to be effective, they must be fairly large, say 100 to 200 acres according to the number of trees contained. These farms would be established throughout the lac-growing area.

A start would be made with suitable sites in existing Government Forest, and the operations subsequently extended by acquisition, as required. Each such farm will require an Overseer and a staff of several guards to supervise the work, guard against theft and issue the brood. It is confidently expected that the farms will not only be self-supporting, but will even bring in revenue, unless a very decided slump occurs in the shellac market. The best localities for such farms are naturally near the local centres of the stick-lac trade, so that they will be within easy reach of the cultivators and are likely to become known and get talked about. Suggestions for suitable sites will be found in the Local Notes attached to this report. It is understood that the Government of Bihar and Orissa are now contemplating a scheme on these lines in Khas Mahal near Daltonganj in the Palamau district of Chota Nagpur. When this farm is in full working order, it may serve as a model.

It is suggested that the whole of the lac be reserved for brood and sold to cultivators or advanced in time of need, when there is assurance that it will be used for the purpose intended, but it is very

important that the price should be carefully settled. If the price of brood-lac is fixed too low, there is a danger, in fact a certainty, that it will be bought up and sold by speculators to the stick-lac dealers. The price must therefore be somewhat above the current stick-lac price, and it is suggested that it be based either on current clean *biuli* lac prices or on Calcutta TN rates. In the former case, as brood-lac contains the stick, the desired safeguard will be secured if it is sold at the local *biuli* rate. If the Calcutta TN rate is adopted as the standard, then different rates will have to be calculated for different kinds of brood :—

Palas brood should be one-half Calcutta TN rates.

Ber and Ghont should be slightly more than half, say three-fifths.

Kusum brood should be seven-tenths of Calcutta TN rates.

These rates will be absolutely fair and a mere fraction of what brood-lac is often sold for nowadays; yet they are sufficiently high to prevent unscrupulous dealers buying up the brood as a speculation in stick-lac, and will ensure that only the man who wants it for propagation will buy it. Any reduction of the price below these figures, as an inducement to purchase, can only defeat its own purpose.

In the management of the brood farms, the following facts must be remembered. For two months in the year, that is one month before the emergence of the larvæ of each brood, the staff will be very busy both collecting and disposing of brood and also infecting and guarding trees within the farm, so that the staff must be large enough to carry on both these operations simultaneously. The brood can be collected for sale about one month before emergence is expected, but during the first fortnight no more should be collected than can be disposed of in a few days. During the second fortnight the whole of the brood may be collected and should be stored in a cool, airy store-room, laid out in rows on bamboo supports. After the brood has emerged any lac remaining will be scraped from the stick and sold in the markets in the ordinary way.

The Overseer in immediate charge of each brood farm should also be qualified to undertake demonstra-

Lac specialists. tion work, and should be encouraged to inspect the lac operations of neighbouring cultivators and zamindars

and to explain the Government methods. In addition, in each of the two important lac provinces, Bihar and Orissa and the Central Provinces, at least one officer—a lac specialist—should be appointed to supervise the work of the farms and to conduct the necessary research operations. The qualifications required in this specialist would be, first and foremost, those of an entomologist, so that he may be in a position to study the insect and its enemies. Some knowledge of Botany is equally necessary and is generally found in an entomologist.

CHAPTER VI.

COLLECTION AND STORAGE.

The collection of lac often begins as early as the latter half of March for Baisakhi and early September for Katki. Needless to say, at these periods the lac is not fully developed and the cultivator collecting so early is deliberately sacrificing an increased yield for the sake of immediate profits, and also in many cases is hoping to minimize the risk of theft. Collection will continue until all the crop, except such as may be reserved for brood, has been harvested. The lac is then separated from the twig either by scraping, by soaking in water and then splitting the twig when the lac falls away (*Ber* only), or, if the lac is *phunki*, by pounding. It must now be carefully dried in the shade and for this purpose is spread out in layers not more than four or five inches deep and repeatedly turned over until dry. *Ari* lac, since it has been collected before the insects swarm, is full of moisture and therefore requires much more careful and prolonged drying than *phunki* lac. Once dried the lac, now known as *dal* lac, is sometimes winnowed to remove all sticks, stones, bits of wood and fibre, sand, and other foreign matter, and is then known as clean stick-lac or *biuli* lac.

Where lac is grown by villagers in the gardens around their houses, the above processes are easily arranged for. When, however, lac is grown on a large scale, considerable attention has to be paid to method and suitable arrangements made so that the stick-lac, cut each day, can be removed from the wood and can start drying from the day of collection. This applies more particularly to *ari* than to *phunki* lac; but, in any case, the quicker the lac is dried and finished, the better.

The above processes are, of course, applied only by the more advanced cultivators. One has only to visit any stick-lac market to realize how careless the preparation of lac may be. Frequently the lac is collected *ari*, when it is thoroughly wet, saturated with moisture, and contains the living bodies of the mother insects distended to large size and occupying fully 25 per cent. of the bulk of the lac. It

will be kept anyhow, in the first place that comes handy, and never touched until a possible purchaser arrives, or until a convenient bazaar day occurs. Heat generates, fermentation sets in, and the result is an evil-smelling mass of lac, wood and fœtid animal remains, which eventually sets into a solid lump known as "blocky" lac. Blocky lac is the bugbear of the manufacturer. Not only is it difficult to crush and to separate the wood and fibre, but the fermentation of the organic matter makes the dye extremely difficult to wash out, the lac itself difficult to melt and the addition of rosin (colophony) a necessity to reduce the melting point. The better class manufacturers will not touch such lac and it is usually purchased at a discount by the makers of TN and lower class shellacs.

The collection of lac cultivated on a large scale presents no easy problem, especially if the method recommended in Chapter V is followed. Such cultivation is nearly always in forests, where labour is more or less difficult to get. It is a fact that most of the lac-growing areas are in *kharij* country, where the field crops ripen in the autumn, comparatively little being grown in *rabi* areas, where spring crops are cultivated. The larger growers of lac, particularly the Damoh Government Forests and the Esociet, have tried to arrange their work so as not to compete for labour with field cultivation. This is the reason why they use the Baisakhi crop primarily for brood and the Katki for the market, despite the fact that there is some reason to believe that Baisakhi lac is of better quality than Katki. If therefore, as has been already suggested, both crops are to be commercial crops, some special arrangements will have to be made.

The following method is suggested for areas where labour is, as it usually is, particularly difficult to get at the beginning of the rains. The proposal is to use both crops as commercial crops, but to use the Katki and not the Baisakhi as the principal brood crop. As soon as the Baisakhi crop matures, that is to say reaches its maximum bulk, as much of it as possible will be collected for the market, leaving as a minimum sufficient only to inoculate the trees in the coupes reserved for the summer brood. The lac used to inoculate these trees will eventually be collected *phunki*. When, in due course, the Katki crop matures, only such lac as is required for brood purposes will be collected before the emergence of the larvæ; the balance will be left on the trees and will be collected *phunki* after

swarming has taken place. During this period, the extension of work by opening up and inoculating new cropping series will be carried out.

The advantages of the system are obvious. The bulk of the work will be carried out in the cold weather ; and more, again, will be done in the hot weather than in the rains. Work in the unhealthy seasons of the year and competition with agriculture for labour are thus reduced to a minimum. It is true that the system does to some extent depart from the general principle already enunciated, that only *phunki* lac should be removed from the forest, for the Baisakhi crop will have to be collected *ari*. This is, however, unavoidable, if lac cultivation is not to compete for labour with field cultivation. Moreover the manufacturer emphasizes particularly the fact that Katki lac contains a larger percentage of colouring matter than Baisakhi, and therefore attaches special importance to the collection and sale of the former in the *phunki* condition.

The above is merely a brief outline of suggestions in one particular case. Modifications will be necessary to meet special conditions, *e.g.*, where *rabi* crops are the staple form of cultivation, or where Kusum is the host-tree. There is one point which can never be over-emphasized. When the lac in one coupe is finally collected, it is essential that all the lac should be removed, whether for the market or for the infection of the next coupe in the series or for both ; otherwise the whole object of the proposal, the resting of the host-trees after a heavy crop, is defeated.

Phunki lac is comparatively easy to deal with. It contains very

Storage. little organic matter and much of the natural moisture of the lac has dried out of

it during the extended period for which the lac has remained on the tree. *Ari* lac is wet and living and must, therefore, be dried much more carefully according to the methods described above. When stick-lac has to be stored, as it frequently must be, it still requires some attention, however carefully it may have been dried. Even *phunki* lac contains some dead larvæ which died naturally, and also the shell of the mother. There is always therefore a liability for the lac to ferment and block. The best method of storage is to keep it in layers of about four to five inches deep in a dry, airy and cool place, where it should be daily raked over. The best apparatus seen

consisted of perforated racks, a good imitation of which can easily be made with strips of bamboo or with bamboo matting.

Many authorities have drawn attention to the fact that considerable loss takes place during the storage of stick-lac owing to the action of predaceous insects. The manufacturers are, however, unanimous that no appreciable loss occurs in their godowns. Both views are possibly correct. If recently cut lac is inspected it will be found to be infested with the larvæ and pupæ of *Eublemma amabilis* and other predators, which must destroy an appreciable quantity of lac. It usually, however, takes weeks and often months for lac to complete its transit from the tree to the manufacturer's godown, and during this period the predators either die or emerge and no appreciable loss will occur actually in the godown. The question whether loss does occur can only be decided after a careful test. In the *Agricultural Journal of India*, Vol. III, pp. 176—7 and in his "Indian Insect Pests" (reproduced by Misra as an appendix) Maxwell Lefroy has described a method of fumigating stick-lac with carbon bisulphide to exterminate these predators. A sample of about one maund of stick-lac freshly plucked and well infested with predators should be divided into two exactly equal parts by weight. One part should be treated as described by Maxwell Lefroy and, after having been cleaned of predators, should be stored so as to prevent reinfection. The other part should be stored in the usual way. At the end of about two months, the co-operation of a careful manufacturer is required, who will convert both samples into grain-lac; and a comparison of the resultant weights will show definitely whether any loss occurs from the action of predators after the lac has been collected. Should appreciable loss occur, the question of preventing it arises. Maxwell Lefroy states that one-and-a-half pounds of carbon bisulphide are required per ton of stick-lac. Carbon bisulphide is an expensive chemical and an arithmetical calculation will show whether the value of the lac saved is more than the cost of saving it or not. If not, experiment is necessary to discover a process involving the use of cheaper chemicals.

Troup (*Indian Forester*, Vol. XXXVII, p. 245, Measures for the destruction of moths predaceous on lac) brings to notice the fact that the emergence of the parasites and predators on lac usually occurs after the swarming of the lac insects. He suggests, as a

method of exterminating them, that all lac should be collected immediately before the swarming, except such as is required for brood purposes, which should be removed as soon as the larvæ have emerged. All lac should be at once removed and treated under moth-tight screens or fumigated as proposed by Maxwell Lefroy (*Agricultural Journal of India*, Vol. III, p. 176). The method seems well worthy of trial and will fit in with the methods of collection of the Baisakhi crop suggested in Chapter VI.

CHAPTER VII.

LAC RENTS AND LEASES.

By far the greater part of the lac-producing area of India is in the hands of the Feudatory Chiefs and large land-owners. It was not so long ago, however, that the landed proprietor began to realize that an appreciable income could be recovered from his tenants on account of lac cultivation. Since then the importance of the industry has increased and in some parts his income from lac is very much greater than that from land rents. In these circumstances, one would expect that all proprietors would take steps to foster and increase the cultivation of lac in their estates; unfortunately there is only too large a proportion of the less enlightened who are only interested in obtaining a maximum of rent from lac cultivators from year to year with little or no provision for extensions.

The systems adopted in leasing the right to cultivate lac naturally vary considerably in different areas. The agreements are either verbal, or consist of a few written terms now more or less stereotyped by custom. Only in Government Forests and in adjoining zamindaris is any complicated form of lease employed. The period of the ordinary agreement between a proprietor and his lac tenant may be one year only, or may extend in Chota Nagpur to three or five years and in the Central Provinces to six or ten years or even longer.

In Hazaribagh and Gaya districts there are two systems, one of cash rents for the right to cultivate, by which the lac becomes the property of the lessee; the other of produce rents, by which the landlord provides the brood and takes seven-eighths of the crop. Independent cultivators will not accept this form of lease, and the commonest practice is for the landlord to take three-fourths of the crop; the brood being supplied by the landlord or lessee according to their relative business acumen. As the cultivator is frequently an aboriginal, and considerably inferior in intelligence to the landlord and his agents, he generally gets the worst of the bargain in one way or another. In many cases, however, tenants have succeeded in establishing a customary right to cultivate lac for which they pay

a fixed rent in cash or produce, and cannot be ejected at the will of the landlord. Cash rents are now becoming more and more popular, and are preferred by the landlords on account of the ease of collection ; they are also preferred by the capitalists and banias, who are now taking an increasing personal interest in cultivation and frequently lease large areas from the zamindars with a view to securing their own supplies of lac.

In Palamau district developments have been slower. The following is quoted from para. 418 of the final report of the Palamau settlement :—

“ It is only within the last thirty years or so that the landlords of Palamau have begun to regard lac seriously as a source of income but since then, spurred on no doubt by the booms of 1895 and 1905, they have done so to such good purpose that the raiyats' former privileges are in most villages annihilated. In a few villages, it is true, the raiyats still hold their lac-bearing trees rent free ; in a very few the trees are included with the holdings in a common assessment ; and in a few more the trees are held upon a fixed rent. But, in the great majority of cases, lac trees are entirely at the disposal of the landlords, and (I quote from Mr. Hignell, a former Deputy Commissioner) ‘ the rates charged are only limited by the landlords' discretion, and the tenants' inability to pay more than the lac on the tree will fetch in the market.’ The trees are let out just before the sowing time. No count is actually made, but the tenant engages for a definite number of trees. The number has nothing to do with the actual facts and is a mere matter of haggling. The landlord's agent endeavours to make the raiyat agree for as large a number as possible, while the raiyat attempts to represent that there are not so many trees available. The rent is fixed later on by the landlord when the crop is ready for cutting ; he considers current prices and the general nature of the crop from his own point of view, and acts in such a manner as to justify Mr. Hignell's criticism.”

In Palamau, Government have decided that tenants in Government estates shall enjoy the annual produce of all trees which grow on their holdings, free of charge. Lac-bearing trees outside such holdings may be given on lease in suitable blocks for a term of five years, preferably to one or other of the settled tenants of the village ; and in such cases the rates are calculated at one anna per tree, or at

half an anna, according to the locality, or even at lower rates at the discretion of the Deputy Commissioner.

In the Kolhan (Singhbhum) Government Estate, the tenants cultivate lac free on Ber trees planted near their holdings and for other trees rent is charged at one anna per tree for Palas, and four annas for Kusum.

In Manbhum the raiyats have full right to cultivate lac on Ber trees in their homestead lands, and pay no separate rent for this right. This is the main type of lac cultivation in this district. For other trees, Palas and Kusum, there is no fixed custom. In one village the raiyats will cultivate without paying rent, in another a rough rental will be charged, and in a third the landlord will do the cultivation himself. The Settlement Department records the rights as they are found.

In the Sonthal Parganas the zamindar is entitled to realize rent (one-half to four annas) for each tree on which lac is grown by raiyats, whether the tree is in the raiyat's holding or not ; but local custom is usually the guide. In Damin-i-koh Government Estate, Government is entitled to collect a separate rent for lac, but does not do so. The export of forest produce is, however, controlled by the Forest Department who collect a royalty under the rules of Re. 1-4-0 per maund, and sell to contractors on a three years' lease the right to collect this royalty in bazaars.

In the Central Provinces, where Government Forests are common, it is only natural to find that the methods of landholders are influenced by the actions of the Forest Department, whose lease forms are often copied almost verbatim. The lac on trees growing on malguzari waste land is the absolute property of the malguzar. That on trees growing in a tenant's holding has now been definitely settled, by section 96 of the Central Provinces Tenancy Act of 1920, which comes into force on 1st July 1921, to be the property of the tenant concerned. The methods employed by the malguzars and zamindars vary considerably. Some will give a lease for a whole estate to a capitalist, who may simply act as a monopolist and sublet the right of cultivation to tenants. In Bhandara the malguzars give out numbers of petty leases for long periods, the agreements being in simple written form, or even merely verbal. Owing to the enormous increases in the value of lac leases in 1919-20,

some unscrupulous landlords took advantage of the ignorance of their lessees to eject them from areas leased, which they were easily able to do since the leases had been irregularly executed. The lessees are now more circumspect and are registering their leases. A curious form of lease was discovered in the Chattisgarh Division. The lessee is a monopolist, and agrees to a minimum purchase rate with the cultivator. The latter, however, is not compelled to sell to the monopolist, and if he wishes to dispose of his lac elsewhere must pay this minimum rate to the lessee. The result is, that the cultivator is encouraged to sell to the monopolist, for, if he sells to anyone else, he has to pay a fine; while the lessee must offer reasonable rates or the cultivator will take his lac elsewhere. Some land-owners, notably the zamindar of Khujji (Drug district), are taking up lac cultivation on their own account and have been realizing very handsome profits. It is hoped that this method will extend, as it will lead to more stable production. At present it is chiefly confined to Mahomedan landlords, as high caste Hindus are deterred by religious scruple from following suit.

Sufficient has been said to show that the smaller landed proprietors, who constitute the majority, take but little interest in lac cultivation, save to secure from their tenants as large a share as possible of the profits of cultivation. So much has this been the case, that, during settlement operations, instances have occurred where tenants have cut down the trees in order that they may not be recorded. This has caused alarm among manufacturers, but no permanent harm results, as the trees coppice, and in a few years are ready to grow lac again. The demands of zamindars undoubtedly have a serious effect on the production of stick-lac, particularly when the market is low or falling. As education spreads, it will undoubtedly be realized that a careful and definite settlement of lac rents is conducive, in the long run, to careful and profitable cultivation. The lenient and far-sighted policy adopted throughout the Government Estates of Bihar and Orissa will, it is hoped, be adopted in their turn by neighbouring zamindars.

As regards Government Forests, serious attention has hitherto been paid to lac only in those of the Central Provinces. There, the usual practice was to lease lac areas to contractors. Sometimes the leases ran for as long as three years, but recently they have been

given for one year only. The following are important clauses in the C. P. type of lac lease. They have occasionally been adopted by other provinces also :—

V. That the lessee agrees :—

* * * * *

(b) that as far as possible all lac shall be collected after the insects have emerged from it ;

(c) to leave unbroken, at each harvest of lac, at least two-thirds of the total quantity of seed-lac on each tree to ensure the propagation of lac during and after the period of this agreement.

Clause Vb. is a dead letter and is hardly necessary in a long lease. In Clause Vc., two-thirds is too high a proportion to ask for, and it is very doubtful if the provisions of this clause are ever carried out in practice.

In 1915—17 a special form of lease was introduced in Damoh, by which the contractor paid entirely on outturn, and a sliding scale of royalty was arrived at by deducting the expenses of cultivation, freight, manufacturing charges, brokerage, and profits, etc., from the average rate of TN shellac at Calcutta, as published by a well-known firm of brokers. The result was divided by two, and was the rate per maund, paid as royalty by the contractor. The expenses were fixed at Rs. 28, so that the formula was, where TN is the rate per maund of TN shellac at Calcutta :—

$$\text{Royalty} = \frac{\text{TN}-28}{2}.$$

The basis of the system is excellent, theoretically. The price of shellac varies widely and the value of stick-lac follows in proportion ; so that if a long term lease is executed for a fixed cash payment, the lessee runs a risk of loss if the price of shellac falls ; whereas if the price rises the lessor gets considerably less for his lac than it is worth. By adopting the Damoh method, both sides are protected. If the price of shellac rises, the royalty paid by the lessee automatically rises, and if the shellac rates fall the royalty paid automatically falls. Thus the lessee is insured against a fall in the market and the lessor is secure of contingent profits following a rise.

Payment by outturn, however, has never been found by the Forest Department to be quite satisfactory. The staff required for

checking purposes is large, and the necessity for each party closely to watch the other invariably breeds ill-feeling among the respective subordinates; relations become strained and the efficiency of the work is bound to suffer. Moreover, it is almost impossible to word the agreement to cover all eventualities. The Damoh lease, sound though it was in principle, was not a success, and on expiry of the period was not renewed. Subsequently the work was done departmentally and has been so successful that it has been decided to extend departmental work to other forests as rapidly as possible, and an officer is to be appointed to carry out research work, to suggest working plans, and generally to advise local officers.

Contracts will, however, continue to be necessary, and the following are suggested as suitable guiding principles for adoption in framing them :—

- (1) In order to ensure that a contractor will interest himself in extending cultivation a long lease is necessary. Ten years is suggested, and six years is the absolute minimum, which will give a contractor a chance of materially extending cultivation and of reaping a fair profit from the result of his industry. Short period leases defeat their own object, for all that the contractor will do will be to get as much lac as possible from the forest during his incumbency and to leave nothing; the next crop is bound to fail and new brood must be introduced, always an expensive matter.
- (2) The last crop in the period of the lease must be left by the contractor until it is *phunki*, so as to provide brood for the next crop; or at least the proprietor (Government) must reserve the right to utilize the last brood for purposes of infection, before surrendering the *phunki* lac to the contractor. For the other crops no restrictions should be placed on the contractor. He may collect the crop as he likes, but should be encouraged to adopt the principles advocated in this report. In addition, the usual clauses, which prevent the felling of trees, etc., must of course be retained.
- (3) It is customary for the Forest Department leases to begin on the 1st of July, and to terminate on the 30th June.

This means that the lease begins and ends just as the summer brood is swarming, a most unsuitable time for a lac lease. The best arrangement is one by which the lease commences on the 1st of April, and ends on the 31st March. The contractor thus gets several months in which to collect his last (winter) crop, *phunki*, and the new contractor gets several months to make his arrangements before the swarming of the summer brood.

- (4) To eliminate the speculative element, a sliding scale of payment should be adopted, based on the Calcutta TN rates. By this means the undesirable contractor who takes up a lac lease solely as a gamble, makes huge profits if it booms, and fails completely if prices fall, is ruled out. The desirable contractor will get a just reward for his industry in extending cultivation; he will get no undue advantage from merely spasmodic increases in prices, but will be protected from loss when prices fall. As a *modus operandi* it is suggested that the sole right to cultivate lac for say ten years, in a selected forest, be put up to open auction. Prior to accepting any bids, the auctioneer will state the Calcutta TN rate of the day, and explain that the bid accepted will be the amount payable during the first year only. To calculate the amount payable in any subsequent year the original bid will be increased or decreased by the same percentage as that by which the average TN rate during the previous year has increased above or decreased below the original Calcutta TN rate at the date of the sale. As an example, let us assume that the forest is leased for ten years on a day when the Calcutta TN rate is Rs. 200 per maund. The highest bid of Rs. 10,000 is accepted and is payable as the price for the first year of the contract. During the first year the Calcutta TN rate fluctuates between Rs. 210 and Rs. 160, the average being Rs. 190. It has, therefore, fallen from Rs. 200 to Rs. 190, a decrease of 5 per cent. During the second year the cultivator will

pay Rs. 10,000 less 5 per cent. Rs. 9,500. During the second year foreign demands increase and the average TN rate goes up to Rs. 250, a rise of 25 per cent. The price payable in the third year is, therefore, Rs. 12,500. During the third year there is a slump to Rs. 100, a decrease of 50 per cent. which ordinarily would be sufficient to ruin the contractor. He is saved, however, by the fact that the price payable during the ensuing year goes down to Rs. 5,000, and he can still cultivate lac at a profit. The chief claim of this system is that, except in the first year, the rate payable at the beginning of each year depends entirely on the profits made by the contractor during the previous year. He is protected against losses due to trade slumps and the owner of the forest gets his share of the profits when trade booms. It is claimed also that the system will tend to stimulate the regular cultivation of lac as the profits will be more uniform.

There may of course be some difficulty in getting the less advanced contractors to realize the merit of the agreement. But once realized, the system is likely to appeal to both parties. The difficulty of ascertaining the correct average price may be overcome by reference to published statistics such as those of Messrs. Moran and Co.

CHAPTER VIII.

MANUFACTURE.—PART I.

It is unnecessary to discuss here in detail the chemistry of lac.

The chemistry of shellac.

This subject has been dealt with very fully by Tschirch (*Die Härze und die Harzbehälter*, pp. 812—830). See also Puran Singh's note on the Chemistry and Trade Forms of Shellac, *Forest Bulletin* No 7. It will suffice to mention that shellac appears to be composed of a complex mixture of resin acids, resin esters and a wax. The resin acids are probably derived from hydroxy fatty acids.

As is well known, shellac in storage gradually becomes less soluble in alcohol and it has been suggested by Puran Singh (*loc. cit.*) who obtained the same results by heating shellac, that this change is due to the formation of either anhydrides or lactones. Puran Singh further states that the solubility of shellac can be restored by soaking in water for some days. The solubility of shellac is of the greatest importance to the manufacturer, and to the consumer who uses shellac in solution. Trade experience seems to indicate that the rate of decrease of solubility is proportionate to the area exposed to the air. Thus grain-lac becomes insoluble more rapidly than shellac, and shellac more rapidly than button-lac. One manufacturer has stated that TN shellac loses 5 per cent. solubility per annum during the first three years, 10 per cent. during the next three years and 15 per cent. in subsequent years.

The quality of shellac appears to depend very largely on the relative proportions of the resin and wax it contains. It has been definitely proved that the proportion of wax to resin in stick-lac is greater than in the shellac manufactured by the manual method (see Hatchett's analyses quoted by Puran Singh—*loc. cit.*) and that the surplus wax is left in the *kiri* or residue. The alcohol processes presumably retain the whole of the wax in the shellac while other machine processes are believed to retain less wax in the shellac than does the manual method. This may be the explanation of the differences between hand-made and machine-made shellac and would indicate the lines on which research in this subject might take. The

manual process has hit off by sheer accident the proportions of resin and wax which produce the best quality shellac known. So little research has, however, been carried out in this branch of the subject that no definite facts can be stated and the true explanation of the difference between hand-made and machine-made shellac may be found to be entirely different from that suggested above.

The properties which appear to make shellac the valuable article it is, are its insolubility in water and ready solubility in other cheap solvents; its comparative hardness among gums; its immunity to change when exposed to the atmosphere; its elasticity and power of adhesion to smooth wood and metal surfaces on which it can be spread in very thin layers; its flux or power to assume with great exactness the shape of a mould to which it is applied; its power of electrical resistance.

At present the requirements of the trade in a good shellac are, firstly, cleanness, freedom from dirt, insoluble matter and adulterants; and, secondly, paleness of colour. Low grade shellacs are dark orange and high grade shellacs run up to a very pale yellow. This prejudice in favour of pale colour can be of no real importance to many consumers, especially to the gramophone record manufacturers who take nearly half of the shellac manufactured. Unfortunately prejudice has so firmly fixed colour as the standard of the trade that even when a more practical standard is discovered it will be difficult to get it recognized.

No complete analysis of shellac has ever been published, and the usual procedure of the chemist to whom samples are submitted for analysis is to apply certain tests from which definite facts can be deduced. The two most important tests are:—

1. The determination of the percentage of insolubles in boiling alcohol.

2. The determination of the percentage of rosin. Details of the methods employed will be found in Allen's Commercial Organic Analysis, Volume IV (London, J. and A. Churchill).

In the old days in India there used to be considerable local prejudice against the manufacture of shellac. There is still current a proverb "Sau kasahi ek lahi"—"One lac manufacturer is as bad as a hundred

Methods of manufacture.
The manual process.

PLATE I.



Coolie women grinding and sifting lac.

butchers"—referring to the destruction of insect life caused by the collection and manufacture of lac. It should not be forgotten that, in its earlier history, the industry concentrated on the manufacture of lac-dye, which was composed chiefly of the bodies of the lac insects. In those days, therefore, it was necessary to collect the lac before the fresh brood had swarmed. This practice still survives although it is unsatisfactory inasmuch as lac is now valued for its resinous properties and not for the dye, which must be entirely washed out if the quality of the shellac is to be good. Hence the proverb and the prejudice survive although they have lost much of their force.

The object of manufacture is principally to refine the crude lac and remove the dye, fibre, animal remains, and other impurities. Care has, however, to be taken that none of the essential qualities of shellac are prejudicially affected by manufacture. The following is the process adopted in the larger factories and, with some modifications, in the smaller factories and in the cottage industry.

The first step is to clean and roughly grade the stick-lac. The process is locally known as *halorna*. The stick-lac is hand-picked, and the broken fragments separated from that still adhering to the parent twig. The former is called *gulla* and, being absolutely the pure raw product, is used for first quality shellacs. The latter is called *phal* and is used for second and third quality shellac.

The *phal* is now sifted (*chalna*) through a No. 6 mesh, and what passes through is called *ekraya*, the lowest quality of unwashed grain-lac or *kachha chaori*. The *phal* which remains on the sieve and also the *gulla* are then ground in stone mills, *chatki* or corn crushing machines, which break off the lac from the stick. The large sized Kusum lac and certain better quality Baisakhi lacs have to have specially adapted rollers to break them up as they will not pass through the ordinary corn-crusher. Sieves and corn-crushers may be worked by hand or steam power.

The lac is now winnowed carefully in basket work trays (*sup*) by women who by this process are able to get lac wonderfully clean of sticks and dirt and are also adepts at recovering the last traces of lac from the refuse.

The lac, now known as unwashed grain-lac (*kachha chaori*), is next taken to the washing department. This consists of a cement floor on which stand rows of stone pots, known as *nand* or *athali*.

These vessels are about 2' 6" high and 2' 6" in diameter at the top and centre, tapering to the base which is about 1' 6" in diameter. The inside surface is rounded and serrated regularly to a depth of about one-tenth of an inch. Above each *nand*, is a horizontal bamboo at a height of about 4 ft. from the ground. The unwashed grain-lac is put into the *nand*, covered with water and allowed to stand overnight. In the morning the washer or Ghasandar (literally "one who rubs") subjects the lac to about three washing operations known as *minjao*. He stands in the *nand*, grasps and leans on a horizontal bamboo and rubs the lac with his feet against the serrated sides. This crushes the lac cells and washes out all the dye.

After the first *minjao* the water is allowed to settle. A scum (*pank*), consisting of fibre and cell matter and a small quantity of lac, gradually forms; it is removed, dried, winnowed and picked to recover as much lac as possible, and then sold to cottage labourers who pick it over by hand for further grains.

After each washing and removal of the scum, the water, which contains the lac-dye in suspension and solution, is run off and generally treated as refuse without value. In some factories, however, the water is collected in vats and the dye allowed to settle for some time, aided by precipitation with lime. It is then recovered, pressed into cakes and sold at a bare profit as commercial dye or *rang batti*. In other cases local field labourers are allowed to remove the dye water for use as manure.

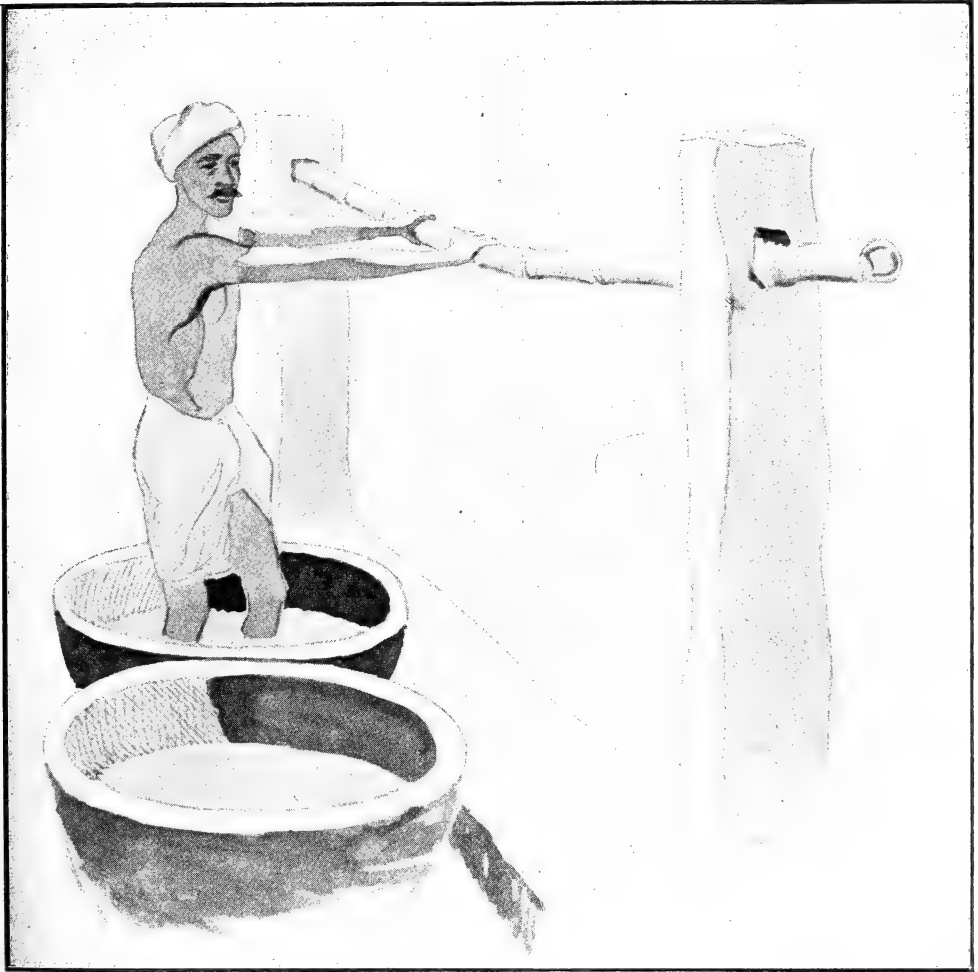
After the third and final washing the grain-lac is taken out of the *nand*, strained through a cloth and washed in a basket with clean water to remove the last traces of dye; it is then spread on a cement floor to dry. It is now known as clean grain-lac or *safa chaori*. The term seed-lac is frequently used synonymously with grain-lac, but as the former term is also used to connote brood-lac, it is advisable to speak only of "grain-lac" and "brood-lac" and so to avoid all risk of ambiguity.

The grain-lac is now winnowed in a *kula* and the following classes separated :—

- | | | | | |
|---------------------------------|-----|-----|-----|---------------|
| 1. <i>Chaori</i> | ... | ... | ... | large grains. |
| 2. <i>Karola</i> or <i>Kuni</i> | ... | ... | ... | small grains. |
| 3. <i>Molamma</i> | ... | ... | ... | fine grains. |

Chaori or *Karola* if made from Kusmi or good Baisakhi have now a fine golden-yellow colour. Poor Baisakhi and Rangeen lac

PLATE. II



The Ghasandar washing grain-lac.

give a darker colour, brown or even dark purple. *Molamma* is a fine dark purple powder.

The grain-lac is now taken to the blending room and mixed in the proportions necessary to produce the different grades of shellac. The *molamma* can only be used in making TN grade shellac and high class manufacturers discard it altogether and sell it to bangle makers. It cannot be used for high grade shellacs as it contains dirt too fine to be easily separated from the lac in the process of manufacture. Very great care is necessary in blending the different kinds of grain-lac, which are of by no means constant quality. Kusum grain-lac is always better than Baisakhi and Baisakhi than Katki; but at the same time Kusum, Baisakhi and Katki all vary with the locality from which they were obtained and with the year and time of the year in which they were collected. Obviously, therefore, if manufacturers are to keep their grades and marks of uniform quality, great skill is required in the blending room. At this stage also most manufacturers add a little yellow sulphide of arsenic or orpiment (*hartal*) as a finely ground paste, thoroughly mixing it with the lac, which is then again dried. This addition is made to meet trade requirements of colour. Grain-lac made from inferior or old stick-lac is known to be difficult to melt, and in this case rosin or colophony is also added to lower the melting point. The proportion of added rosin is generally 12 per cent but it is only used in TN manufacture. The rosin used is Canadian pure rosin; Indian rosin has been tried but is not satisfactory. Rosinous shellac is always sold as such and in view of trade requirements it can hardly be looked on as an adulterant.

The blended lac is now taken to the firing room and poured dry into cloth bags (*thaili*) sausage-shaped and about 30 ft. long by 2 inches in diameter. These bags are generally of cotton and, for the higher grade shellacs, closely woven; or even two bags, one inside the other, are used to ensure closer filtration. The chief operator in the firing room is the roaster or Karigar, a skilled and highly paid workman. He is assisted by the shellac stretcher or Bhilwaya, also skilled, and the bag twister or Phirwaya, an unskilled worker. The fire-place or *bhatta* is of Dutch oven shape about 3 ft. long, 1½ ft. high and 1 ft. in depth and contains a charcoal fire. Immediately in front of the *bhatta* is a smooth flat stone or *dongi* at one end of

which is a sunken depression or *pathri* containing water. The Karigar's implements are :—

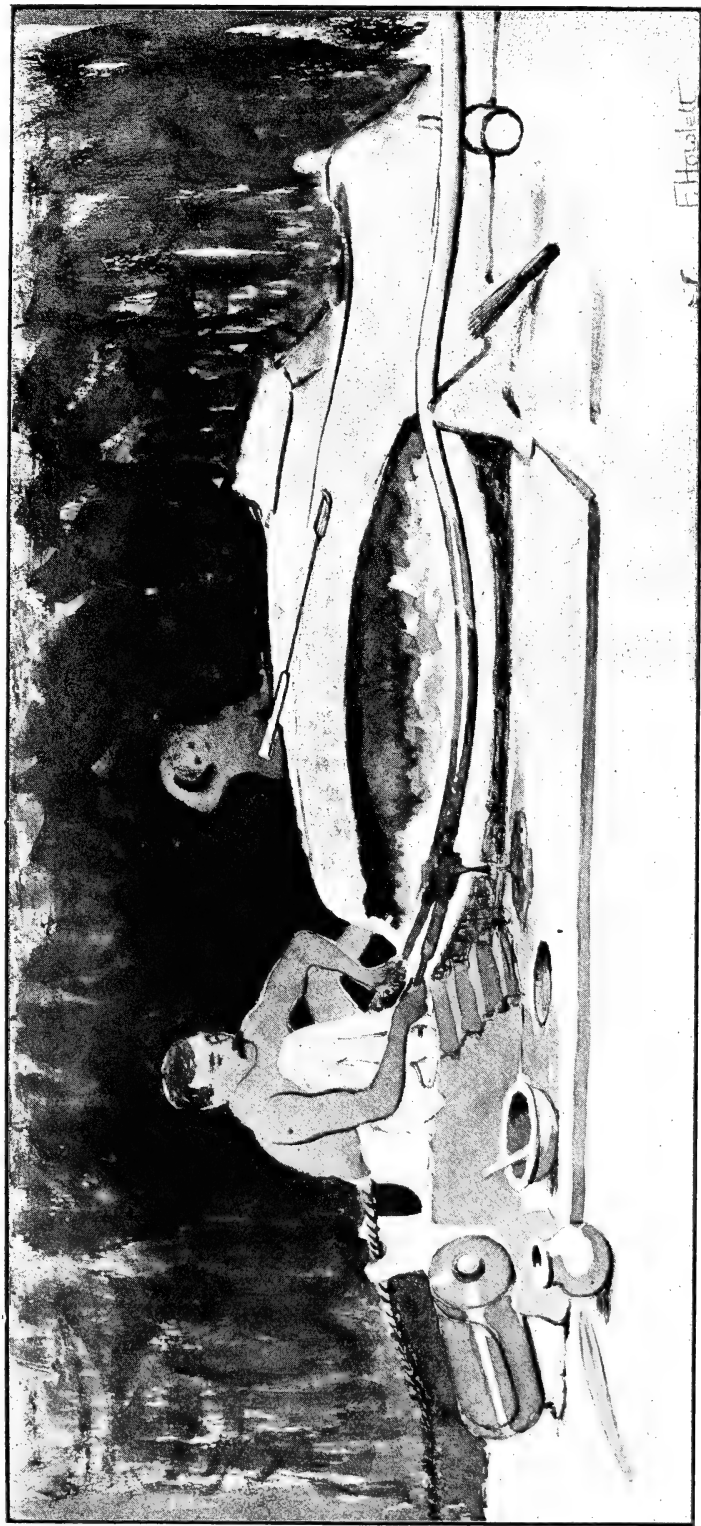
- (1) A baster or *charna*, a flat piece of iron $8'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$ with a wooden handle.
- (2) A spatula or *pirbanda* similar to the baster but with no handle.
- (3) A gouge or *kirkhodni* to rip up the bag and thus remove the refuse or *kiri*.
- (4) A small bladed shovel or *karchhula* for attending to the fire.

The Bhilwaya uses the following implements :—

- (1) A glazed porcelain cylinder 10' in diameter and 2' 6" long, full of warm water. It is known as the *pipa*, and lies at a gentle slope from the ground.
- (2) A strip of palm leaf or *nera*.
- (3) A piece of cloth.

The Phirwaya has a *charki* or *chorki*, a simple windlass, such as is used in rope making, and a row of wooden guide blocks with pegs called *dhanna*. The bag lies along the wooden blocks and one end is attached to the *charki*.

The Karigar sits at one end of the *bhatta*, just protected from the direct heat of the fire. The portion of the bag in front of the fire is called the *pera* and this is gradually twisted by the Phirwaya by means of the *charki*, so that it is thoroughly and evenly heated through on all sides. The Karigar then seizes his end of the bag tight in his hand. This action results in the *pera* being tightly twisted and in the lac being expressed through the cloth. The Karigar scrapes it off with the *charna* and throws it on to the *dongi*, kept damp with water from the *pathri*. Thence he repeatedly bastes it on the *pera* until it is thoroughly mixed and, by evaporation of the water, attains the correct consistency. He then takes it up on the spatula and pours the glutinous mass over the porcelain cylinder. The Bhilwaya spreads it out on the cylinder with his palm frond, polishes it with the cloth and then removes the sheet carefully from the cylinder. Seizing it with hands, feet and mouth, he stretches it from its original size of about 2' by $1\frac{1}{2}''$ to about 4' or 5' by 3' or 4', warming it in front of the fire every now and then to soften and anneal it. The process of manufacture is now finished. Each of



The Karigar melting lac.

the sheets so made (called a *panna*) when dry and hard is broken up into small pieces ; irregular fragments (*e.g.*, where the sheet was held) are picked out for remelting and the result is shellac (*chapra*) ready to be packed in cases for export. When a large quantity of refuse or *kiri* has accumulated in the *pera*, the Karigar stabs it with the gouge and squeezes out the refuse or *kiri* which is pressed into cakes. Even *kiri* contains a large quantity of shellac and is usually sold for the manufacture of bangles.

When a bag is completely worked out it is twisted up to about $\frac{1}{2}$ " diameter and sets into a hard stiff rod known as *danri*. The *danri* is boiled in a cauldron of water with Fuller's earth (*reh* or *sajjimatti*). The encrusted lac is thus recovered from the cloth, and floats as a scum on the water from which it is scooped off and pressed into cakes, called *passewa*, which can be remelted for TN manufacture. The washed bags are mended by *darzis* (tailors) and again used.

The process for manufacturing garnet and button lac is similar to the above, but in the case of garnet lac the process is finished when the lac is removed from the cylinder ; it is not stretched, but is allowed to set hard. In making button lac, the Karigar has a spatula with the end turned up in a "U" shape. He scoops up portions of lac with this and pours them on a metal plate or palm stem where they spread out into a flat button about $2\frac{1}{2}$ " in diameter by $\frac{1}{4}$ " thick and set hard. Before they set the Bhilwaya stamps the firm's trade-mark on each button. The use of a palm stem is said to give a better polish to the buttons.

The above description applies to a good class factory employing primitive methods. The smaller factories manufacturing only TN and Standard I, and also the workers in their own homes, do not necessarily go through the processes exactly as described, but in all essentials they are the same. In Jhalda and Balarampur (Manbhum district) the *nands* or washing vessels are usually sunk in the cement floor. The Ghasandar kneels down at the side of the *nand*, and the washing is done with the hands instead of the feet. In Jhalda many of the manufacturers use steam power to drive their crushing machines and some use mechanical washers consisting of horizontal cylindrical iron vessels within which revolves a bar carrying arms throughout its length. Water is supplied and the revolving arms break up the lac cells. It is claimed that by means of these machines

clean grain-lac can be produced faster and more economically than by the ordinary method. In washing the grain-lac, if a high grade superfine shellac is to be manufactured, a little Fuller's earth is added to the washing water. This, however, dissolves some of the lac, causing a loss of about 5 per cent.

The Mechanical Process.

Mechanical methods are chiefly confined to a few factories in Calcutta among which the principal are—

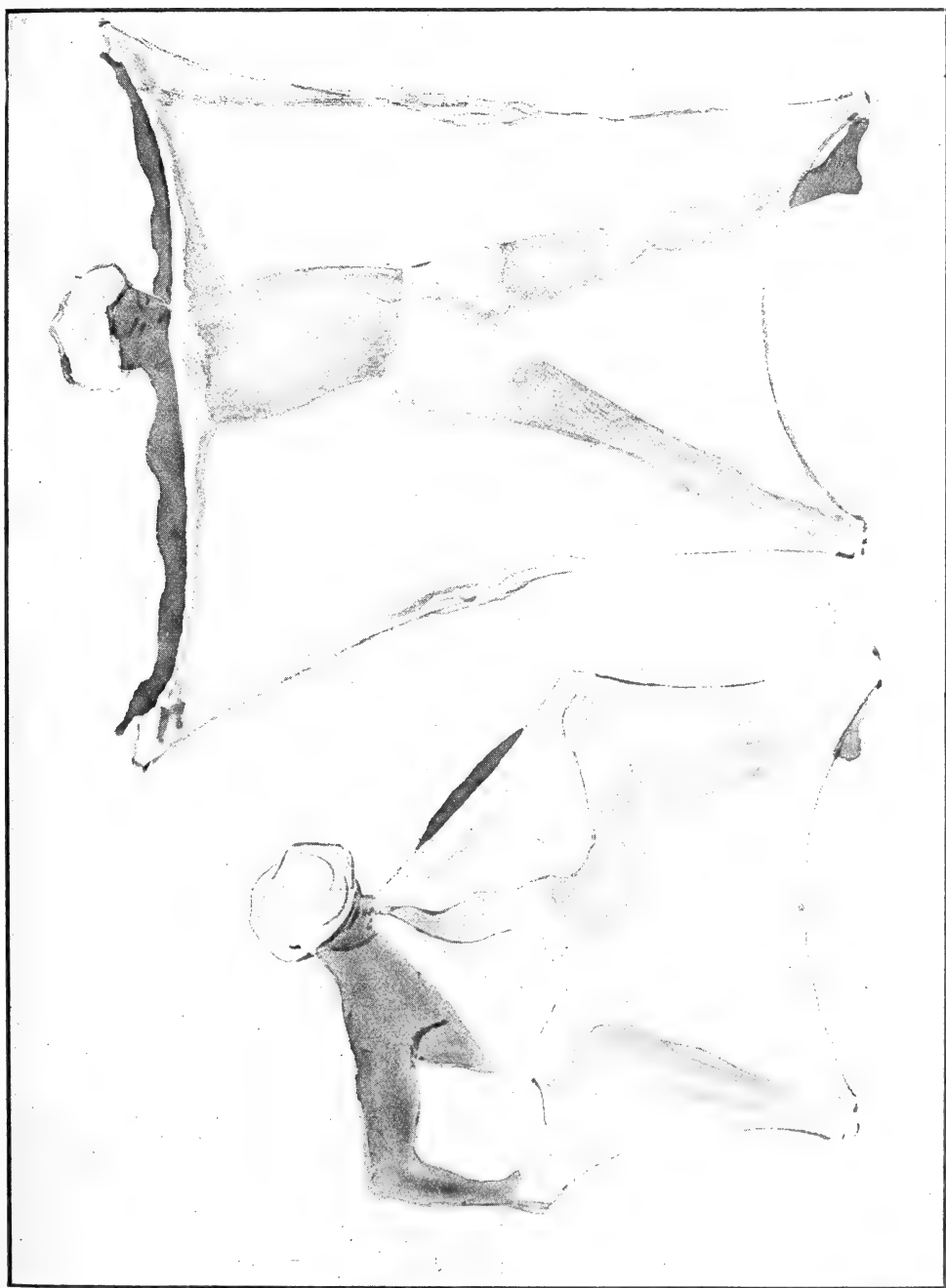
Messrs., Angelo Bros., Ltd., of Cossipore ;

J. Galstaun, Esq.

There used also to be a mechanical factory in Rangoon, which however closed down in 1914 ; and the Esociet, Ltd., of Maihar, C. I., also manufacture shellac by machinery. Messrs. Angelo Bros. manufacture both garnet lac and orange shellac. The former is made by an alcohol process whilst orange is melted out by means of steam heat. Their best known mark is A. C. Garnet ; and, of orange shellac, AB-TN, TN No. 1 and TN No. 2. The other manufacturers also have their own marks.

Alcohol solvents are generally used in the mechanical process, but little detailed information is available regarding the actual processes employed, which are in the nature of trade secrets. The apparatus consists of a mixer, an evaporator, and a condenser. Washed grain-lac is placed in the mixer, sufficient alcohol added and the whole agitated and heated until dissolved. The hot solution is now run off through a filter cloth into the evaporator where the alcohol, driven off by heat from a steam jacket, passes through a condenser back to the mixer. The clean molten shellac is drawn off through a tap in the bottom of the evaporator and made up into the form of garnet lac or shellac as required.

The chief advantages of the mechanical over the manual method are that shellac can be turned out more rapidly and in much larger quantities, is cleaner and more uniform. Practically all the available lac is extracted from the stick-lac. Indeed by the mechanical agency lac can even be extracted in remunerative quantities from *kiri* and other refuse, chiefly for conversion into the cheaper grades of garnet lac.



The Bhilwaya stretching shellac.

On the other hand it is doubtful whether the mechanical process can produce a shellac so suitable for all purposes as the hand-made shellac. The precise difference between the two products has never been discovered, but a difference undoubtedly exists, and the successful manufacturer by mechanical methods will be he who is able to ascertain and neutralize this difference. Certain it is that, in removing the last traces of alcohol from the shellac, it is very difficult to avoid dehydration and consequent insolubility, and also some darkening of colour. The machinery employed is expensive and hence, if the stick-lac supply is short and the machines cannot work regularly, the capital charges are high.

There is undoubtedly a big future before the mechanical process as soon as these and connected problems can be solved. Their solution should only be a matter of time and research.

Numerous alternative methods have been suggested for the mechanical manufacture of shellac and numerous patents have been registered. Puran Singh suggests the use of wood spirit (methyl alcohol) as an alternative for methylated spirit (ethyl alcohol) and brings forward sound arguments in favour of its use. Other investigators suggest solution in an alkali, filtration, and precipitation with an acid, or the use of centrifugal force to filter molten lac directly from its impurities. Their success has yet to be established.

Kiri or *Phog* is the refuse remaining in the bags after the shellac has been squeezed out. It is a black and sticky mass and is pressed while still warm into cakes about one inch thick and eight to ten inches in diameter. It consists of animal remains, fibre and woody material, with a large proportion of lac resin and a considerable quantity of lac-wax. It is worked up in different ways :—

The By-products of Shellac Manufacture.

- (1) *Kiri* from the manufacture of high grade shellac is mixed with stick-lac and used in the manufacture of TN.
- (2) It is bought by machine manufacturers in India and abroad and used for the manufacture of garnet lac by the alcohol process.
- (3) It is used in local Indian industries; principally the manufacture of bangles and toys.

There is always a ready market for *kiri*, which fetches prices about one-quarter to one-fifth of the price of TN. The yield is four to five seers of *kiri* to each maund of good shellac.

Passewa is the substance which is boiled out of the bags after shellac has been made. It is whitish and opaque and, as it has been boiled out of the bags with the help of Fuller's earth, it is probably somewhat hydrolised. It is used in blends for TN manufacture and fetches about one-half the price of TN. The yield is about $\frac{1}{2}$ seer per maund of shellac.

Molamma is the fine dust sifted out of grain-lac. It consists of very fine grains of lac mixed with powdered wood, animal remains, mineral dust, etc. The yield is about two seers per maund of good shellac. It is used in TN manufacture and for bangles and other uses to which *kiri* is put.

Lac-dye or *Rangbatti* was originally the staple product of the lac industry, and was prized for its bright scarlet shade ; it was used, for example, to dye the British infantryman's tunic. It is interesting to note that the word "lake" in Crimson lake is derived from lac—and the word "crimson" from the Arabic *kirmiz* (insects), from which the Urdu *kiri* is also directly derived. Puran Singh in his "Note on the Chemistry and Trade Forms of Shellac" summarizes our existing knowledge of the chemistry of lac-dye. It is naturally fast to silk and wool but not to cotton ; as stated in the Introduction, its place has been taken by aniline dyes and between 1880—1890 it ceased to have any commercial importance. Nowadays the majority of the manufacturers throw it away, but some work it up and find a small market for it in India, where it is used for the preparation of *altas*, balls of cotton wool soaked in the dye and used by Hindu women for colouring the soles of their feet. It is occasionally also used as a manure. During the recent war when other dyes were not procurable there was a slight demand for it and its price rose as high as Rs. 15 per maund, but this was only a temporary revival.

Manufacturers would give much to be able to re-establish a market for lac-dye. It should not be forgotten, however, that the dye suffers from all the defects inherent in natural dye-stuffs. The following summary of the present position in regard to lac-dye has been kindly

supplied by a well-known firm of carpet manufacturers who have given it full and careful trial :—

- (1) Lac-dye cannot compete with the synthetic dyes unless it is put on the market in a cleaner and handier form.
- (2) The use of synthetic dye-stuffs is much easier. Lac-dye is not always uniform and the adjustment of the quantities of mordants used with it requires great skill and care.
- (3) The synthetic dyes are much cleaner in use, one pound doing the work of 20 lbs. of lac-dye as at present put on the market. The refuse in the lac-dye fouls the yarn and often leads to a percentage of the hanks being so badly dyed as to be unusable. There is no such loss with synthetic dyes.
- (4) The principal mordants used, salts of tin, are expensive and rather unstable.
- (5) It is difficult to shade lac-dye with other dye-stuffs without the expense of a second dye bath.
- (6) The shades obtainable with lac-dye are more restricted than those obtainable with blends of good synthetic dyes.

From the above facts, it is obvious that, if lac-dye is ever to compete with synthetic dyes, a means must be devised by which the essential dyeing agent contained in it can be extracted almost pure, standardized, and put on the market in a clean and handy form.

Lac-wax is hardly yet a by-product of lac manufacture as suitable means have not yet been devised for isolating it from *kiri*. At present it is only recovered by precipitation during the manufacture of bleached shellac. It is harder than bees-wax and has been reported on favourably by polish manufacturers.

Shellac is usually packed by manufacturers in two-maund wooden

Packing and Storage. cases, lined with cloth. Two maunds (164 lbs.) is approximately $1\frac{1}{2}$ cwt. (= 168 lbs.)

and shellac is sold on this basis in England and America. It is sometimes also packed in double gunny bags, the use of which increased when packing cases grew scarce during the war. The grade of shellac is usually marked on the outside of the box, but in the case of button lac the buttons are also stamped with the maker's mark.

Shellac should always be stored in a cool dry place and it is advisable that it should not be shipped during the extreme hot weather and rains, when there is always a risk of its arriving in a set or "blocky" condition. An allowance is made to the importer for blocky shellac, to cover the additional cost of having it freed.

CHAPTER IX.

MANUFACTURE.—PART II.

Mirzapur has always been and is still the home of shellac manufacture. Indeed, practically the whole manufacturing industry used to be concentrated at Mirzapur, which before the days of railways was a convenient centre for the collection of stick-lac by road from the principal producing areas, and for the despatch of shellac by river to Calcutta. With the development of railways, however, the importance of Mirzapur has declined. It is awkwardly situated from the point of view of rail transport, for it lies outside the direct route leading from the main stick-lac markets to Calcutta. In future, it is likely to become gradually a manufacturing centre of minor importance, working up lac from the United Provinces, the Punjab and Hyderabad (Sind). The following figures illustrate the decline in the importance of Mirzapur as a manufacturing centre :—

Year.	INDIA'S TOTAL PRODUCTION.			
	Imports of stick lac into Mirzapur.	Calcutta export in cases of 2 maunds.	Equivalent in stick-lac maunds.	Percentage of total stick-lac production which was manufactured in Mirzapur.
	Mds.	Mds.	Mds.	Per cent.
1901—1905 ...	1,032,000	699,500	2,798,000	37
1906—1910 ...	1,714,000	1,197,000	4,788,000	35
1914—1918 ...	996,000	1,103,500	4,414,000	25

After Mirzapur and Calcutta the principal centres now are, in order of importance,—

Balarampur ..	...	...	} Manbhum District.
Jhalda ...	...	...
Pakaur ...	...	...	Sonthal Parganas.
Imamganj ...	...	...	Gaya District.
Umaria ...	...	...	Rewah State.
Ranchi ...	...	...	} Ranchi District.
Bundu ...	...	...

In addition to these, there are small centres at Gondia (C. P.), Chakardarpur (Singbhum), Chandel (Manbhum), Purulia (Manbhum), Daltonganj (Palamau), and Maihar (C. I.); and small factories frequently appear and disappear in any small town or village in the lac areas. The production of lac has developed faster in Bihar and Orissa than in the Central Provinces. In fact Bihar and Orissa is now capable of manufacturing the whole of its raw lac and imports large quantities from the Central Provinces. Manufacture in the Central Provinces has hitherto developed very little, and the stimulus recently given to lac cultivation in those Provinces should be turned to useful account by local manufacturers. Almost any railway station on the Bengal-Nagpur broad gauge line would seem to provide a suitable locality for a factory. The climate is dry during the greater part of the year and the manufacturer will only need to consider the question of water-supply and labour. Raipur in particular is very close to a large Kusum supply area at Rajim and Dhamtari; it is in easy communication with Gondia, Katni (including Damoh) and Pendra, all large Baisakhi and Katki markets, and is only a few miles further from Calcutta than is Mirzapur. Labour is plentiful and cheap though skilled labour must, of course, be imported from Mirzapur until local labour can be trained.

The bulk of the shellac manufactured is known as *TN*. This mark is a standard of the trade and is non-proprietary. It has been in existence for a long time—so long indeed that its origin cannot now be accurately traced. The following derivations have been suggested, the first of which is the most probable :—

Grades.

- (1) That it was originally the mark of Taluram Naturam, manufacturer of Belarpur.
- (2) That it was originally the mark of Triloki Nath, Bengali.
- (3) America suggests that it stands for "Truly Native." This seems very unlikely.

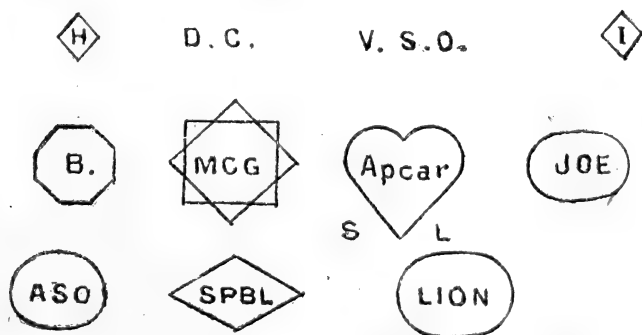
Though it is a universally recognized standard the quality of *TN* is not fixed, but varies from year to year with the quality of the stick-lac crops from which it is manufactured; and the London market makes its own standard each year from the first few shipments. *TN* as such is pure shellac with a limit of 3 per cent. insoluble impurities. It contains no rosin. Rosinous shellac is sold

as such and is manufactured to contain 10 to 12 per cent. rosin. Calcutta brokers blend this with pure TN to make a 3 per cent. mixture which is a standard in London. The quality clause in the standard form of contract adopted by the London Shellac Trade Association runs as follows :—

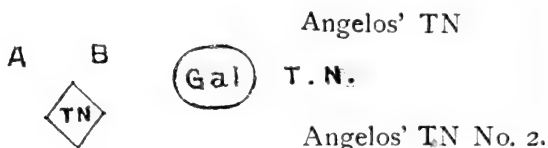
“Guaranteed to be of equal value to standard sample of TN and not to contain more than 3 per cent. of adulterating matter or if inferior thereto a fair allowance to be made.” Similarly, the New York market recognizes “ordinary pure TN” which must, however, be free from rosin ; but has established, in addition, a grade known as “Ussa TN” containing 3 per cent. of rosin.

Superior to TN is Standard I, another non-proprietary mark. It is only a clean grade of TN and differs from it in no other essential except a slightly better colour and fewer impurities. It contains no rosin, and fetches three to five rupees more than clean TN. TN and Standard I are manufactured only from Baisakhi and inferior lacs, and not from Kusmi. The better Baisakhi is used for Standard I while poor Baisakhi, Katki and rejections from fine grade manufacture are used for TN. The bulk of the TN and Standard I is made in small factories. The larger factories usually make better qualities and only make TN when they cannot get good stick-lac or wish to use up their rejections.

Superior to Standard I are the “Fines” and “Superfines”—practically all proprietary marks. They are usually manufactured from the very best Baisakhi lac with or without a proportion of Kusmi, while the very finest grades are made from pure Kusmi. The following are well-known marks of this class, as quoted by Messrs. Moran in their weekly statement :—



The Calcutta market will not accept machine-made shellacs as TN. They are therefore made and sold as proprietary marks. The marks quoted by Messrs. Moran are—



Bleached shellac, though not exactly a separate grade, is a special form of shellac used in making white varnishes and for other purposes in which a white colour is required. There are various methods of preparation which are described by Puran Singh, usually a reducing agent is employed of which chlorine is the commonest. Bleached shellac rapidly loses its solubility unless kept under water and it must therefore be made immediately before use. Its manufacture in India for export is thus hardly a practical proposition.

Shellac inferior to TN is known as "*dom.*" It is not generally recognized as a definite grade but is bought and sold at a discount on the current rate for TN. A notoriously poor class of shellac is manufactured at Imamganj, and the use of the term "Imamganj" has now broadened so as to cover any inferior TN.

Button lac is sold at a lower price than shellac of the same grade, as it does not go through the process of stretching, and hence the cost of manufacture is less. It is not so popular in foreign markets, as it has generally to be ground before use. There are roughly four grades :—

- (a) Pure Button lacs made from good grain-lac and graded up in values from the equivalent of Standard I shellac to that of D.C.—V.S.O.—Octagon B.
- (b) Pure Black Button lacs made from *kiri*, *molamma*, etc., and sold at about TN prices.
- (c) Button lacs made from good grain-lacs, but containing 20 to 30 per cent. of rosin and sold in various grades, some cheaper others dearer than TN.
- (d) Black Button lacs made from *kiri*, *molamma*, etc., but with rosin admixture and sold much below TN rates.

Garnet lac is usually of inferior quality containing 10 to 12 per cent. of rosin and has also to be ground before use. The principal marks quoted by Messrs. Moran & Co. are—



The consumers of shellac in the U. S. A. have advocated the creation of a definite series of official grades of shellac, to which manufacturers should be asked to approximate their marks. This proposal does not meet with the approval of the better class manufacturers in India as the individuality of their marks would be lost and with it the premium now paid for consistent quality. Further the speculation in shellac, now confined to TN and Standard I, would be extended to all grades. The larger the number of private marks manufactured, the less is the tendency to speculation. No true speculator dare now offer a high grade shellac unless he has the full quantity actually in his godown, in which case the business is scarcely speculative; for he has only one source of supply, namely, the actual manufacturer of the particular grade. If the standards of high grade shellac are official, any one will be able to manufacture them and the speculator will be tempted to gamble in them.

Prior to 1914 the actual cost of TN manufacture was about Rs. 7 per maund, but since the war prices have risen considerably and the following may be taken as about correct :—

	Rs.	a.	p.
Crushing, sifting and washing to convert the stick-lac into grain-lac	1	8	0
Cloth for bags	2	8	0
Thread for bags	0	4	0
Labour (at the fires)	3	0	0
Charcoal	1	8	0
Orpiment	0	4	0
Soda for boiling bags	0	4	0
Fuel for boiling bags	0	4	0
Total	9	8	0

The cost of manufacturing TN is therefore about Rs. 10 per maund. It will be noticed that no account has been taken of overhead charges or of interest on capital. The bulk of the TN is

manufactured in small factories where the owner is either himself a workman or personally supervises the work. The cost of the *nands*, stoves and other implements is so small that the eight annas added above to make the round figure Rs. 10 more than covers the interest on capital expenditure. The large manufacturer certainly employs highly paid supervising staff, but his outturn is so large that the actual incidence per maund is small and his expert supervision enables him to produce shellac of high quality, the extra value of which more than covers the cost of expert supervision. The cost of manufacture can therefore be fairly estimated at an average of Rs. 10 per maund of shellac.

And now with regard to the raw material. The quality of stick-lac varies so much that it is always sold and bought on an estimate of the amount of *biuli* lac or of grain-lac which it contains. The former is clean stick-lac free from twigs and dirt; the latter has already been described in the preceding chapter. Both *biuli* and grain-lac give a known and constant yield of shellac to the manufacturer; the chief variations are those due to quality or season. The following are the calculations commonly adopted in conversion:—

Biuli Lac.

One maund	Kusmi	ari	yields	32—33	seers	grain-lac.
„	„	Jethwi	„	31	„	„
„	„	Baisakhi	„	26—28	„	„
„	„	„	Phunki	30	„	„
„	„	Katki	ari	16—20	„	„
„	„	„	Phunki	26—28	„	„

Grain-lac.

One maund	Baisakhi	or	Katki	grain-lac	yields	30	seers	of	shellac.
„	„	Kusmi	or	Jethwi	„	36	„	„	„

Of course in the more careless methods of TN manufacture the inclusion of dirt, grit, etc., in the shellac will increase the yield. TN is, however, rarely made only from stick-lac; *kiri*, *molamma*, and *passewa* are nearly always included in the formulæ.

As the value of shellac is always fluctuating the manufacturers use calculating tables which show the price they can afford to pay for stick-lac against each Calcutta TN quotation.

In the case of many manufacturing industries, the bulk of the manufactured goods are sold forward, often over periods of weeks or even months. The manufacturer bases his quotation, firstly, on

current prices of the raw material and finished article, and, secondly, on an estimate of the future trend of these prices. His profit will depend on his being able to secure a satisfactory margin between the price of the raw material and the price secured under his contract for the finished goods. The manufacture of shellac is an industry of this class. As already shown, the stick-lac markets are highly speculative. To some extent stick-lac quotations follow the course of Calcutta TN prices, but they naturally fluctuate to a greater degree than TN, chiefly because the extent of forthcoming supplies cannot be even approximately estimated in advance; and hence the future trend of the TN market is the subject of the wildest guesswork. Even the manufacturers of private marks are misled in their estimates and postpone their purchases of stick-lac too late or purchase too early against forward sales of their marks. Still more is this the case with the manufacturers of TN, who are usually men of small means in the hands of big local dealers. They depend entirely for success on attempts to estimate accurately the forward trend of stick-lac and TN rates; and too frequently they are caught short of their raw material which they are compelled to purchase at a disadvantageous time, forcing up prices against each other. Chart No. I compares fluctuations in the prices of stick-lac and TN during 1912 and 1913, and illustrates the wide fluctuations of the former in comparison with the latter.

The solid line represents the cost of stick-lac required to make one maund of TN shellac, to which is added all charges for manufacture and marketing in Calcutta; the table on the chart shows how these figures were obtained. The monthly prices of stick-lac were supplied by a Calcutta manufacturer and, to ensure accuracy, the exact factors for conversion on which he based his *biuli* prices have been used (Note that the lac is *ari*, not *phunki*). The interrupted line shows the price one maund of TN actually fetched in Calcutta. The two lines continually cross and recross one another. When the TN (interrupted) line is above the solid line there is a manufacturing margin of profit. When the solid line is above the interrupted the manufacturer who buys his stick-lac and sells his shellac on the same day must lose. The double and single shading on the chart show respectively periods of loss and profit on manufacture and spot sale.

It will be observed that, during the whole of 1912, Calcutta TN prices were low; from chart No. II the cause is seen to be the large stocks held in London. At the same time supplies of stick-lac were ample, and manufacturers, therefore, had matters much their own way, with the result that practically throughout 1912 there was a small manufacturing margin of profit and Calcutta prices fluctuated very little. In 1913 conditions changed. The stick-lac crop was poor, and this factor, combined with a slight decrease in the London stocks, caused a big advance in Calcutta prices. TN prices fluctuated considerably and owing to the shortage of the crop the stick-lac prices fluctuated even more violently, with the result that the interrupted line is, more often than not, below the solid line, showing that spot sales did not yield a profit.

The first step required to stabilize the trade is to ensure a steady supply of stick-lac and the second is to provide an early and reliable forecast of each crop. A tour of the stick-lac districts makes it quite clear that increased production is more feasible than has hitherto been supposed. In fact it is not unlikely that Manbhum or Ranchi districts alone, if they produced their largest possible outturn of stick-lac (an unattainable ideal), could provide the whole of the world's requirements. At present the total Indian supply is, more often than not, less than the demand. The action Government can take with the object of regularizing supply may be direct or indirect. The direct method is by developing lac cultivation in the extensive Government forests. This has begun in the Central Provinces where departmental work has already trebled the supply in Damoh. The Local Government is extending this work to other districts and is appointing a special staff including a special department for research. In view of present scarcity conditions in the foreign markets there can be very little fear of over-production for some years to come. The indirect method of Government action is twofold: firstly, the formation of brood and demonstration farms throughout the lac districts, as advocated in Chapter IV. The importance of these farms cannot be too strongly emphasized. Secondly, much good would result from the publication of authoritative periodical reports on the crop, based on the experience obtained in Government forests. These reports need not at first give quantitative estimates but should show in some detail the effects of climatic conditions.

Another point that may be brought to notice is that Government should do everything possible to encourage the production of the better qualities of lac. With this object in view the propagation of Kusum lac might be encouraged in preference to other varieties where the choice can be made; and, after Kusum, of Ber and Ghont lac. If high grade stick-lac is available the production of high grade shellac will increase at the expense of TN; the paramount influence of TN on all markets will decrease and with it the tendency to speculation.

CHAPTER X.

INTERNAL TRADE OF INDIA.

The distribution of lac cultivation in India has already been described in detail. It is not often realised how scattered cultivation is; how wide the total area; and in some cases how scanty and difficult are means of communications. A very high proportion of the whole area consists of jungle tracts from which the cultivators bring the stick-lac often long distances by road or river to the nearest bazaar, which is not itself necessarily situated on or even close to a railway.

The following is a list of the principal stick-lac markets of India with an estimate of the crops arranged as Kusmi, Jethwi, Baisakhi and Katki. The names of the districts are those in which the markets are situated, and not necessarily those in which the lac is grown. Thus Imamganj is situated in Gaya district, but much of the Imamganj lac comes from Palamau and Hazaribagh districts; Jhalda is in Manbhum district, but perhaps one-half of the Jhalda lac is grown in Ranchi and Hazaribagh districts. The estimates are very rough and can have no pretensions to accuracy. They do not represent bumper crops but merely crops secured during good average years:—

Province.	District.	Market.	CROPS IN MAUNDS.				
			Kusmi.	Jethwi.	Baisakhi.	Katki.	Total.
Bihar and Orissa.	Manbhum	Balarampur ...	12,000	5,000	25,000	10,000	52,000
		Jhalda ...	25,000	8,000	45,000	16,000	94,000
		Chas ...	...	...	10,000	5,000	15,000
		Manbazar ...	...	...	20,000	6,000	26,000
		Katras ...	...	...	2,000	1,000	3,000
		Gobindpur ...	...	...	2,000	1,000	3,000
	Ranchi..	Ranchi ...	20,000	10,000	35,000	20,000	85,000
		Bundu ...					
		Lohardaga ...					
		Khunti ...					
		Managhatta ...					

Province.	District.	Market.	CROPS IN MAUNDS.				
			Kusmi.	Jethwi.	Baisakhi.	Katki.	Total.
Bihar and Orissa.	Hazaribagh.	Chatra ...	} 5,000	2,000	20,000	10,000	37,000
		Hazaribagh ...					
	Gaya ...	Imamganj ...	...	...	40,000	20,000	60,000
	Palamau	Daltonganj ...	...	...	30,000	15,000	45,000
		Garhwa ...	3,000	1,500	40,000	20,000	64,500
	Saran ...	Chapra and other small markets	...	...	2,000	1,000	3,000
	Sonthal Parganas.	Pakaur, etc. ...	...	...	75,000	20,000	95,000
		Dumka ...	...	...	2,000	1,000	3,000
	Singhbhum	Chaibassa ...	} 15,000	10,000	30,000	25,000	80,000
		Chakardarpur...					
		Gamaria ...					
		Tatanagar, etc.					
Central Provinces.	Sambalpur	Jharsaguda ...	} 1,000	500	2,000	1,000	4,500
		Sambalpur ..					
		Rajgangpur (O. F. S.)					
	Bilaspur	Pendra including Bilaspur ...	} 2,000	500	20,000	10,000	32,500
		Champa, Sakti					
		Raigarh (O.F.S.)					
		Akaltara, etc.					
	Raipur	Rajim ...	20,000	10,000	2,000	2,000	34,000
		Dhamtari (including Balod) ...	10,000	5,000	1,000	1,000	17,000
	Bhandara	Gondia includes Balaghat ...	} ...	..	40,000	50,000	90,000
		Mandla ...					
		Seoni ...					
		Chhindwara ...					
		Chanda ...					

Province.	District.	Market.	CROPS IN MAUNDS.				Total.
			Kusmi.	Jethwi.	Baisakhi.	Katki.	
United Provinces.	Damoh	Government Forests ...	...	...	500	4,500	5,000
	Jubbulpore	Katni ...	600	300	25,000	10,000	35,900
		Sihora ...	...	...	5,000	2,000	7,000
		Jubbulpore ...	600	300	6,000	4,000	10,900
	Hoshangabad.	Bankheri ...	3,000	2,000	2,000	1,000	8,000
		Itarsi including Narsinghpur ...					
	Mirzapur	Ahaura ...	...	...	5,000	2,200	7,200
	Bahraich	Mathara & Ris-sia	...	...	2,000	3,000	5,000
	Aligarh	Hathras ...	...	...	1,000	1,000	2,000
	Lucknow	Lucknow ...	...	...	1,000	1,000	2,000
	Kheri	Singhai ...	...	...	2,000	2,000	4,000
	Cawnpore	Cawnpore ...	...	...	1,000	1,000	2,000
	Saharanpur	Saharanpur ...	...	...	3,000	2,000	5,000
	Bareilly	Bareilly ...	...	...	3,000	1,000	4,000
Punjab ...	Hoshiarpur	Hoshiarpur } Una	...	...	15,000	10,000	25,000
	Rest of the Punjab.	...	...	...	5,000	3,000	8,000
Central India.	Rewah Ste.	Umaria ...	1,000	...	30,000	20,000	51,000
	Esociet	Maihar ...	...	...	4,000	2,000	6,000
	Bhopal	Bhopal ...	...	...	2,000	1,000	3,000
Bombay	Sind	Hyderabad, etc.	...	...	20,000	6,000	26,000
	Rest of Bombay.	...	...	...	1,000	1,000	2,000
Burma	...	...	...	...	20,000	10,000	30,000
Assam	...	...	...	...	20,000	15,000	35,000
			118,200	55,100	616,500	337,700	1,127,500

The total production may thus be estimated at over a million maunds of stick-lac, of which each cultivator is usually responsible for not more than a few seers.

As a result of these conditions—the scattered character of the industry and the long distances by cooly, cart or boat, as well as by train, to the important markets—the crude stick-lac has to pass through many hands on its way from the cultivator to the factory. The organization required for this trade is very complicated. Its outposts consist of a large number of stick-lac markets which are really centres of collection in more or less close touch both with producing areas on the one hand and with manufacturing centres on the other. But this trade does not follow any very clearly defined routes, for stick-lac will be attracted to different markets from one season to another and will be passed on at all seasons to any one or more of the manufacturing centres. No history of the internal trade of India would be complete without some account of the agents who carry it on. The following are the principal links in the chain :—

The first agent is the cultivator or *raiya* on whose efforts rests the whole fabric of the lac industry of India. As already described the cultivator is normally a person of poor education and small means who cultivates an acre or two of land on lease from a zamindar. His holding may include a few trees suitable for the production of lac ; or he may take a lease of suitable trees on uncultivated lands outside ; or again he may act as an employee of the zamindar himself or of a contractor dependent on the zamindar. There is this difference, however, between the lac industry and agricultural industries proper, that whereas the latter are staple industries, the former merely provides the cultivator with subsidiary earnings to supplement those obtained from agriculture. A natural consequence is that the lac industry as a whole tends to be quickly affected by factors which would not affect a staple industry. When the price of lac is low trees may be neglected and production may fall off comparatively quickly ; and production may be similarly affected through the indolence of the cultivator if the agricultural season is good and he is obtaining full prices for his field crops. It thus happens that the margin of production in the case of lac is considerably wider and more elastic than is usual in the case of agricultural industries proper. An expert in local conditions of the industry would be able to draw a series of concentric rings round any important bazaar, and to describe roughly the relative distances from which lac will

be worth collecting and bringing to market at different levels of price.

The next link in the chain is the *Baipari*, a wandering trader equipped with a cart or a few pack bullocks, who wanders from village to village selling salt and other commodities and buying up local products of which lac is one. His methods of business are many and vary according to the class of person with whom he is dealing. With the aboriginal living in the depths of the jungle his dealings are generally in kind, so many seers of salt or other commodity being given in exchange for lac. Naturally the Baipari with his general knowledge of market prices always gets the best of the bargain. In his dealings with the more sophisticated cultivators, the bargaining is usually for cash and is much closer, as there is more competition and the seller has more opportunity of learning the trend of events in the markets. The Baipari is usually a man of small means and is frequently financed by the Arhatiya, who retains a lien on the lac and has the right to arrange for its sale.

The centre of the whole system of up-country distribution is the *Arhatiya* or *Ardar*, the commission agent or broker. He is usually a man of substance, shopkeeper, money-lender, agent and auctioneer, and lac-broking is generally only one of his many activities. He is purely an agent and never actually owns the lac which passes through his godown, but sells it on commission. He takes commission from the seller at a percentage of the price obtained, usually about 1 per cent., and from the buyer at so much per maund of lac bought, usually about Re. 1. His remuneration seems high but he acts as surety for the buyer, and if the latter fails to pay up the Arhatiya is responsible to the seller for the value of the lac. When selling to firms of well-known standing, he frequently reduces his commission considerably below the rate he would ask from dealers of doubtful financial stability.

The method of sale differs in different districts. Sometimes it is open auction, when the purchasers will inspect the lac offered by the Arhatiya, make their own estimates of its value and bid accordingly. Another and very common method is the cloth method of secret auction. The Arhatiya, the seller and the buyers all sit in a ring round the lac to be sold. Each extends his right hand into the middle of the ring; the hands are covered by a cloth and bids are

made to the Arhatiya by signs under the cloth. The Arhatiya then by similar signs conveys particulars of the highest bid to the seller, who agrees or not to the sale. The signs are by the fingers and the value of a finger depends on the rates at which lac is being sold at the time. If prices are in the neighbourhood of Rs. 40 per maund, the offer is conveyed by two grasps. The first will intimate the tens, each finger grasped representing Rs. 10. At the second grasp, each finger joint represents one rupee. For example, if a buyer wishes to bid Rs. 35 he will grasp the first three fingers of the Arhatiya's hand to show Rs. 30 and then the whole of the first finger to show Rs. 3 and two joints of the second finger to show Rs. 2. When the sale is completed, the Arhatiya signifies the fact by whipping away the cloth and throwing a handful of lac into the lap of the successful bidder.

The purchasers of lac may be agents of large manufacturers who are paid a small retaining fee and a commission on purchases effected. More usually they are dealers, frequently Marwari by caste, who buy up the lac as a speculation and take it to the manufacturing towns, retailing it to the small manufacturers as required. The dealer is generally a man of substance, and at first sight appears to be a mere parasite of the trade. Were this a fact, he would rapidly disappear as the lac trade is very keenly competitive and no true parasite could survive the operations of a single season. The *raison d'être* of the dealer is not far to seek. The majority of the manufacturers are small men of little capital, who cannot afford to send agents to the stick-lac markets. Further, the lac harvest is reaped during comparatively short periods of each year and the small manufacturer is rarely able to buy sufficient to last him until the next crop comes in. This is where the dealer's intervention is essential. He buys lac as an investment and doles it out to the manufacturer as soon as the latter has converted earlier purchases into shellac, sold the shellac, realized the price, and is thus in a position to buy again. A further advantage in the case of a commodity of values so fluctuating as those of lac is the dealer's participation in the risk. The dealer undoubtedly plays an important part in the financing of the industry and is honourably entitled to his share of the profits.

Each crop takes as a rule two months to pass completely through the markets. The speculative element is strong, for any given consignment of lac may change hands several times up-country before

it reaches the Arhatiya and again in the manufacturing centre before it reaches the manufacturer. On the other hand the large manufacturers and large cultivators aim at eliminating as many as possible of the middle-men. For example, most of the important manufacturers employ agents to purchase on their behalf at each of the big markets, and those agents again employ sub-agents to purchase in the districts. The agent buys as best he can, direct from the Baipari, or through the Arhatiya, and his sub-agent in a large measure replaces the Baipari. He is daily informed, by wire from his head office, of the quantities and qualities required and the prices he may pay. Occasionally an Arhatiya will take up an agency on behalf of a manufacturer. It should be remembered, however, that the number of manufacturers who are able to adopt these methods is comparatively small, and that the bulk of the lac passes through the ordinary channels. The price of stick-lac in Indian markets thus follows very closely the Calcutta prices of TN shellac, and fluctuates as local forecasts of the trend of the Calcutta market are more or less optimistic.

In the internal lac trade of India, the chief interest centres in the innumerable transactions which cover the journey of the crude lac from the tree to the factory. The transit of the finished article, orange, garnet or button lac, from the factory to the port is less eventful. It follows more ordinary lines of trade and can be described in a few words.

Lines of Shellac Trade.

Practically all up-country shellac is attracted to Calcutta for export; the export trade from Bombay, Karachi, Madras, and Rangoon is negligible. Between the up-country manufacturer and the Calcutta merchant-shipper, who undertakes the actual shipments to foreign countries, stands in some cases a dealer, in some cases a broker and sometimes both. The Calcutta dealer is naturally a man of bigger standing than the up-country dealer. He is often a Marwari with considerable capital at his back, handling other produce besides shellac. He has agents in the manufacturing centres who purchase shellac and rail it to Calcutta on his account. In some cases also he purchases locally from the Calcutta agents of the better class of up-country manufacturers. By this means he may accumulate considerable stocks in Calcutta which he will sell, when the market is favourable, to the brokers or to the merchants or to other dealers.

He may, of course, act as a commission agent and secure supplies for a principal; but, in most cases, the shellac is his own property, of which he disposes at the highest available rates.

The broker on the other hand works, in theory at any rate, purely on a commission basis. He also has his agents in up-country markets and thus keeps in touch with forthcoming supplies and their prices. He visits the offices of the principal shippers, ascertains their requirements, with particulars of quantity, quality and price, and closes the business on offers received through his up-country agents.

The shipper is usually a merchant of good standing with principals or agents in London, New York and other foreign markets. Three-quarters of the export trade is conducted on the basis of "forward delivery" contracts, and the quality is then guaranteed to a type such as TN, St. I, etc. So far as spot goods are concerned, the merchant purchases on samples brought to him by the brokers or dealers and is influenced chiefly by the lightness of the colour in estimating the value of a consignment. He will also, to be on the safe side, secure from a local analytical chemist a certificate showing on analysis the percentage of rosin admixture or the freedom from rosin. The class of business preferred is naturally that wherein a definite offer is received by cable from London or New York, which can be accepted if shellac is available at a suitable price or rejected if it is not. The profits in this business are rarely high, but they are certain. In the alternative, offers may be cabled to London or New York firms for acceptance or refusal. Or, again, shipments may be made to London or New York agents for consignment sale if the trend of prices in the foreign market seems favourable.

The local industries of India at present employing lac as a raw

material are not numerous, but there is
Local industries. no reason why these local demands should

not increase. Imitation fruits and toy animals are made of lac, or of wood coated with lac. The Indian toy trade is still in its infancy, but steps are being taken by the Commercial Intelligence Department of Calcutta, in conjunction with Directors of Industries in India and with the Indian Trade Commissioner in London, to interest foreign markets in Indian toys. Bangles are manufactured from *kiri*. Gramophone records are turned out in

large quantities in Calcutta. The manufacture of crude micanite, from alternate layers of mica splittings and shellac, has been started at Kodarma, an important mica centre, and should progress to the manufacture of the finished article. A considerable quantity of shellac is also used in the manufacture of Indian paints, varnishes and sealing-wax. Finally there seems to be no reason why India should not manufacture and export lac-wax, a hard white wax suitable for polishes, and a successful rival to canauba wax. At present, however, the proportion of lac required for industrial purposes in India is small in comparison with the export trade.

There have been so many complaints in foreign markets as to the speculative character of the shellac trade, the number of unnecessary middlemen in India and serious fluctuations of Indian prices, that the subject calls for special comment. Speculation must be frankly admitted. But very few of our foreign critics realize the peculiar circumstances of the industry, on which it is hoped that the present chapter will have thrown some light. Some 80 million pounds of stick-lac are collected during two principal seasons of the year from centres so far apart as Hyderabad (Sind) in the west, and the Shan States in the east. On the average, no single cultivator is responsible for more than a few pounds of this enormous total, and each quota must pass through many hands before it finally reaches the manufacturing centres on the East Indian and Bengal-Nagpur Railways, from which the finished product is railed to Calcutta. Although the expenses of propagation and again of manufacture are not high, the expenses of collection are considerable ; and in the very nature of the case the risks must be distributed amongst a large number of agents, chiefly men of small education and less means. As the next chapter will show, the foreign demands for shellac are keen and increasing, and Calcutta is practically the only source of supply. At the same time, estimates of forthcoming crops are, also in the very nature of the case, extremely difficult to make ; indeed from the total available quantity is never really known until all has come in.

While the extent of forthcoming supplies is so uncertain the extent of the foreign demand is more easily gauged. Every increase or decrease of London stocks, qualified by up-to-date information as to shipments, is an indication of the weakness or strength of the

demand. Chart No. II illustrates the close relation between London stocks and Calcutta prices, which rise as the stocks decline and fall as they expand.

As London stocks through the medium of London prices affect the Calcutta TN rate, so do Calcutta rates affect the prices paid up-country for lac entering the stick-lac and manufacturing markets. These markets are in close telegraphic communication with Calcutta, and every fluctuation in the Calcutta prices gives rise to up-country estimates of fluctuations to follow.

Fluctuations in the Calcutta TN rate are thus due chiefly to the inter-action of demand and supply in foreign markets, which are handicapped, moreover, by uncertain information as to the volume of forthcoming supplies. Speculation is bound to flourish in this atmosphere. It may, and certainly does, accentuate the fluctuations of price of which, however, it cannot be described as the primary cause. As education spreads, the disturbing factors will undoubtedly diminish, but this is a matter of time. The more direct remedies suggested, the departmental propagation and distribution of brood-lac and demonstration of improved methods, the preparation and distribution of accurate crop forecasts, the organization of research work and publication of results should undoubtedly contribute to steady the trade.

CHAPTER XI.

FOREIGN TRADE.

The following table gives particulars of the Indian export trade in shellac, garnet and button lac since 1901. Packing is either in cases or in double gunny bags containing two maunds or approximately $1\frac{1}{2}$ cwts. each. This unit has been adopted and for convenience round figures have been given:—

Exports of Shellac, Garnet and Button Lac in cases of 2 mds. or $1\frac{1}{2}$ cwt.

	1901	1902	1903	1904	1905	1906
United Kingdom ...	35,500	59,500	65,500	79,000	42,000	38,500
U. S. A. ...	45,000	48,000	55,500	52,500	73,500	82,500
France ...	5,500	1,500	4,000	3,500	7,000	2,500
Germany ...	22,500	14,500	19,000	17,500	30,000	28,500
Holland and ...						
Austria ...						
Japan ...	3,000	3,000	3,000	4,500	5,000	4,500
Other Countries ...						
Total ...	111,500	126,500	147,000	157,000	157,500	156,500

	1907	1908	1909	1910	1911	1912	1913
United Kingdom ...	55,500	65,000	72,500	83,000	50,500	50,000	53,000
U. S. A. ...	84,500	79,000	155,000	118,000	91,000	111,000	94,000
France ...	7,500	10,500	9,500	15,500	11,500	16,500	9,500
Germany ...	52,500	59,000	72,000	64,000	66,000	63,500	27,500
Holland and ...							
Austria ...							
Japan ...	7,000	8,500	12,500	9,500	16,000	13,000	8,500
Other Countries ...							
Total ...	207,000	222,000	321,500	290,000	235,000	254,000	192,500

	1914	1915	1916	1917	1918	1919
United Kingdom ...	54,500	58,000	46,000	40,000	58,000	56,000
U. S. A. ...	114,500	161,500	154,500	142,500	108,000	139,000
France ...	8,000	10,000	6,500	500	6,000	5,450
Germany ...	35,000	...	...	...	..	450
Holland and ...						
Austria ...						
Japan ...	2,500	6,500	10,000	8,500	12,500	600
Other Countries ...	17,000	7,500	19,000	4,500	12,000	3,500
Total ...	231,500	243,500	236,000	196,000	196,500	205,000

It will be observed that the United States of America are by far the best customer. Exports to the Continent were chiefly on account of Germany, not merely for her own requirements, but also for re-export to Russia and other neighbours. Trade with the Continent naturally fell off during the war, and shows little sign of recovery at present. During 1919 200 cases of orange shellac were shipped to Hamburg and 250 to Rotterdam.

Before the war, the purchases of the United Kingdom were increasing, but largely for re-export to other countries. The above statement does not, of course, give a true indication of the relative consumption at destination. The United States of America and the United Kingdom are now India's best customers and the following figures give a more accurate indication of the relative consumption in these two countries respectively :—

Average annual consumption of shellac.

During the five years preceding the war (1909-10 to 1913-14).		During the five subsequent years (1914-15 to 1918-19).	
Cases.		Cases.	
U. K. ...	38,000	39,000	
U. S. A. ...	119,000	140,000	

The consumption figures for the United Kingdom have been arrived at by deducting from the imports during each period the

re-exports during that period, and then adding or subtracting the amount by which stocks decreased or increased. For example, during the earlier and latter periods of five years, imports less re-exports averaged 48,000 and 24,000 cases, respectively. During the earlier period, however, stocks had increased from 50,000 to 100,000 cases, and the allowance for these additions to stock reduces the average consumption from 48,000 to 38,000 cases. During the latter period stocks declined from 100,000 to 25,000 cases, and the allowance for this depletion raises the average annual consumption from 24,000 to 39,000 cases. Figures representing stocks in the United States of America are not available, and the consumption figures given above show merely the average imports into the States less the average re-exports during each period.

The total export trade in shellac has increased materially during the 19 years under review. Naturally, as London stocks have their effects on London and Calcutta prices, so also the prices affect production. Unfortunately, accurate figures of production are not available, but local consumption in India, which is confined largely to *kiri*, is, such as it is, fairly constant, and may be neglected. Moreover supplies cannot be held up long in India for fear of "blocking" in the Indian summer and rains. And thus the total volume of exports during any year is a safe indication of the total production during that year.

During the first four years of the period, from 1901 to 1904, foreign demands increased materially. Although statistics of the gramophone trade are not recorded in the Official Customs returns of the United States until 1909, it is an undoubted fact that large and increasing quantities of shellac were being used for gramophone records before that year. The demand on account of electrical apparatus was also increasing. Hence the rise in exports from 111,500 cases in 1901 to 157,000 in 1904. By 1905 London stocks had increased materially. Prices sagged and the trade did not expand during 1905 and 1906. By 1907 stocks were low and prices very firm, resulting in a large advance in production and exports, from 207,000 cases in 1907 to the enormous total of 321,500 cases in 1909, a record which has never since been exceeded. During these years, however, London stocks were gradually built up again, and even the ensuing decline in prices and exports did not result in

any material reduction of stocks, which stood at between 90,000 and 100,000 cases during the five years 1911—15.

The decline in exports was arrested by the outbreak of war, and during the war they averaged over 200,000 cases. By 1918 stocks were gradually depleted in the European markets, and although munitions stocks were fairly high, these did not suffice for commercial purposes when peace was declared. The consuming industries of the United Kingdom and America were in urgent need of shellac, and the result was a general scramble for supplies, for which almost any price was paid. Unfortunately, both the 1918 and 1919 crops were short in India and the stringency was thus accentuated. It is a significant fact that the absence of Germany as a rival purchaser has not been noticed. Fortunately, the 1920 crop promises well. It will be interesting to see if, in view of the keen demand, the record export of 1909 will again be reached.

In Chapter VIII have been described the various processes

employed for the preparation of lac for the
Foreign Demands. market. A very small proportion is

exported in the crude form of stick-lac, and it is unlikely that this proportion will increase materially, partly because it involves the payment of ocean freight on sticks, dust and other impurities naturally adhering to lac, and partly because manufacture in India is cheap. A small proportion is also exported in the partially prepared form of grain-lac, and as garnet and button lac. Orange shellac constitutes the vast bulk of the exports. The proportions in which the different classes are required in foreign markets have developed in favour of shellac as the following figures show :—

Proportional exports of				During four pre-war years (average of 1911 to 1914).	During four years (average of 1915 to 1918).	During 1919.
Shellac	...	...	...	82.1	87.0	89.6
Garnet lac	...	...	...	7.3	5.6	5.7
Button lac	...	...	...	5.8	1.4	3.1
Grain-lac	...	...	...	3.4	5.0	1.1
Stick-lac	...	...	...	1.4	1.0	.5

From time to time the suggestion has been made that the export trade could be conducted more cheaply and more efficiently in the form of grain-lac. Shellac appears, however, to be the most suitable form from the point of view of foreign manufacturing industries requiring pure lac. It is true that a large proportion of these industries require that lac shall be dissolved before use, and that the impurities, normally present in grain-lac, can then be strained off. But conversion into shellac reduces these impurities to a minimum, and facilitates the appraisement of colour. Moreover it is believed that the natural resin and wax are not intimately mixed in grain-lac which has not therefore the important property of a good flux, required by gramophone record and other manufacturers using lac in powdered form and not in solution. Finally grain-lac is said to lose its solubility more rapidly than shellac and on this count alone would be less popular with the consumer. Both the United States Shellac Importers' Association of New York and the London Shellac Trade Association have definitely stated their views that lac arrives in a cleaner and generally more convenient form as shellac than as grain-lac.

On the question of admixture of rosin, the opinions of foreign consumers are divided. The New York market works on a clean basis free from rosin, whereas London works on a basis which allows 3 per cent. of foreign matter. The admixture of rosin in the manufacture of shellac with a view to lowering the melting-point has been a recognized practice for many years past. For some purposes, *e.g.*, the hat trade, the presence of rosin is generally preferred. Where rosin is used in manufacture, the proportion is generally 10 to 12 per cent. and this proportion is reduced by the dealer or broker to 3 per cent. by blending with pure shellac. Pure shellac is just as freely available as shellac manufactured with rosin, and the view that rosin is invariably used, in smaller or greater proportions, is wholly incorrect.

The same remarks apply generally to the use of orpiment, which is frequently employed in the manufacture of shellac in order to improve the colour. Dark colour in shellac usually indicates that the dye has not been completely washed out, and gives rise to the suspicion that other impurities also, such as dust, are present. This suspicion is not always well-founded. It is hoped that the prejudice in favour of light colour shellac, encouraging as it does the admixture

of orpiment, which really serves no useful purpose to the ultimate consumer, will diminish in course of time.

The whole question of the adulteration of shellac, as of other Indian products, is one of great importance

Adulteration.

deserving special study. As already observed, the vast bulk of Indian shellac is produced by petty manufacturers, who are too often tempted by high prices to secure additional weight by adulteration. The commonest form of adulteration consists in the deliberate admixture of sand, ashes or even sugar with the grain-lac packed into the melting bag. The bag itself is purposely prepared of coarse drill, with the result that more or less fine particles of the adulterant pass through the bag with the molten lac, and add to the weight of the finished article. The degree of adulteration naturally increases when the demand for shellac is keen and prices are high. When prices fall and the purchaser can show greater discrimination, the practice is discouraged.

Adulteration will undoubtedly decrease as education extends and the trade becomes better organized. Possibly also there is room for improvement in the commercial tests at present applied. The commercial analyses most commonly employed are Parry's in London and Langmuir's in New York ; but both methods attach more importance to the rosin admixture than to the quantity and quality of other foreign substances. Under the old form of Calcutta contract the penalty clause provided for an allowance of eight annas per maund for each percentage of rosin admixture up to four per cent., and one rupee per maund for each percentage over four. But practically no notice was taken of other foreign substances. Under the new form of contract, the allowance is one rupee per maund for each percentage of rosin up to four per cent., and two rupees for each percentage over four. With regard to other foreign substances, three per cent. are allowed free. The penalty is eight annas per maund for each percentage over three to five and one rupee per maund for each percentage above five.

The treatment of shellac naturally varies with its quality and the

Uses.

use to which it is to be put. For varnish manufacture, it is reduced to a liquid by the use either of alcohol or of an alkali. In some cases, as in the manufacture of gramophone records, it is simply ground to a powder,

mixed with other materials and heated before use. White shellac is obtained by bleaching.

Twenty years ago, the principal uses of shellac were for varnishes and polishes, gums and cements; for sealing-wax and lithographic inks; and last, but not least, as stiffening material in the manufacture of hats. It has also been applied as an insulating substance in the manufacture of electrical machinery and as a binding material in the manufacture of gramophone records. These two last mentioned uses have since considerably expanded; and, in addition, a host of other uses have developed. A London expert has described the principal modern uses of the different varieties of lac in that market as follows :—
“ High grade lacs are used for fine varnishes, for aeroplanes, pianos, furniture, shells (ammunition), sealing-wax, hats (silk, felt and straw), boot finish manufactures, gramophone records, and emery wheels.

“ Low grade lacs for cheaper varnishes, for furniture, hats, sealing-wax, and for making bleached lac, for munitions (cartridges and shells) and for insulating purposes.

“ Button lac is used for sealing-wax, hats, brushes, polishes, etc.

“ Garnet is used for polishes, stains, hats (felt), sealing-wax, and emery wheels.

“ Grain-lac is used for lacquering metals and cables.”

In America shellac is required for even wider purposes of which the following may be given as typical :—

“ Abrasives and emery wheels, varnishes and polishes of all descriptions, billiard balls, moulding and picture frames, saws, glazed paper, photographic supplies, musical and optical instruments, watches, leather, oil-less bees-wax, guns, oil-cloth, paper board, lead pencils, paint and glass, tiles, automobiles, sealing-wax, hats, rubber tires, chemicals and drugs, phonograph records, pianola rolls, composition materials, electrical apparatus of all sorts, brushes and brooms, horse shoes, buttons, lacquer, foundry supplies, bottle tops, fly papers, hardware, toys, sports goods, typewriters, cements and glues, cutlery, mirrors, jewellery, confectionery, engravers' supplies, mint supplies and fireworks.”

An expert has estimated that 40 to 50 per cent. of the entire demand is on account of gramophone records and that no other single industry can account for more than 5 to 8 per cent. of the consumption.

The demand is thus steadily increasing, Not only is shellac driving out inferior materials hitherto considered as suitable, but it is also established as a vital necessity to expanding industries. The chief danger lies in the present high prices which merely encourage the search for a substitute. Hitherto the search has not been to any serious extent successful. During the war, when supplies of shellac for commercial purposes were restricted, the Merchants' Association of New York was asked by the War Trade Board to what extent the commercial consumption of shellac could be restricted and what substitutes were available. The reply was that, unless sufficient quantities of shellac could be brought to America to supply the normal demands of manufacturers, many industries would have to close down. The experience of Germany has been much the same. Synthetic substitutes had been evolved before the war, and were improved during the war, but still remain inferior to the natural product. So far as present prices in Germany go, the natural product is very much more expensive. It can only be purchased from Holland at prices ranging from 120 to 150 and even 200 marks per kilogramme, whereas synthetic substitutes can be secured at from 24 to 32 marks wholesale or 36 to 40 marks retail. The substitute can, however, only be obtained in very limited quantities, as the necessary raw materials, and particularly coal, are lacking. Moreover, it is reported in evidence of the indifferent quality of the substitute that German firms "are unable to deliver electrical machinery to tropical countries because the consistency of the insulating material made of artificial shellac and of mica powder is so poor that it melts in the heat."

It would be unsafe, however, to infer that the danger of the evolution of a successful substitute for shellac is not very real. The surest safeguard is to develop and extend production until supplies more nearly equal the demand, and prices fall in consequence to a more reasonable level. The departmental cultivation of lac by the Forest Department and the organization of supplies of brood-lac should help to secure this result ; and it is hoped that the efforts of the Lac Traders' Association, now in process of formation in Calcutta, will be directed to the same end.

CHAPTER XII.

SUMMARY OF RECOMMENDATIONS.

The principal defects from which the lac industry at present suffers are, firstly, speculation and secondly, adulteration. Both have their origin in the peculiar conditions of the industry ; the ignorance and improvidence of the cultivator ; the long distances from which stick-lac has to be brought to the markets ; the large number of agents through whose hands it passes ; and the difficulty of estimating forthcoming supplies. The following general remedies have been suggested in the preceding chapters.

In the first place, production should be stimulated in order that supplies may more nearly equal the foreign demand, which shows every tendency to increase. A detailed scheme is outlined in Chapter V for improved methods of cultivation on intensive lines, which might be adopted in Government Forests suitable for lac cultivation. In fact departmental working should, wherever possible, take the place of the present contract system which practical experience has shown to be unsatisfactory. In the second place, where any choice is possible in the selection of host-trees, preference should be given to those which produce the better qualities of lac. Thirdly, the greatest importance is attached to the organization of brood and demonstration farms in order that zamindars and cultivators may be assured of constant supplies of brood-lac of good quality, and may learn scientific methods of cultivation and collection.

It is suggested that action on the above lines should be undertaken where possible by provincial Forest Departments. The results should be not merely beneficial to private cultivators, but should also with careful organization bring in no small accession of revenue. The two Governments chiefly concerned are those of Bihar and Orissa and the Central Provinces. Other Local Governments and many States will doubtless find it to their advantage to adopt similar methods. The two Governments mentioned would also be advised to appoint specialists to supervise the organization of lac farms and to undertake research in scientific methods of cultivation and collection.

Further measures suggested for Government enterprise are the publication of periodical reports on crop conditions in areas for which reliable information is forthcoming ; and also the organization of co-operative credit societies for the maintenance and distribution of adequate supplies of brood-lac and for co-operative action in the extension of cultivation.

On the scientific side the late Mr. F. M. Howlett has suggested in Appendix III lines of research bearing chiefly on the life histories of the insect and its enemies and on the chemistry of lac. These investigations are, however, beyond the scope of provincial Forest Departments, and it is suggested that they should be undertaken by the trade itself. For this purpose funds may be made available by the imposition of a small cess on exports, and the funds administered by the Lac Traders' Association now in course of formation in Calcutta, on much the same lines as the Indian Tea Cess is administered by the Indian Tea Association. Expenditure on research may be roughly estimated at one lakh of rupees per annum. As exports during recent years have averaged 200,000 chests yearly, a cess of only eight annas per chest would give the required sum and would provide for expansion as trade increased. Later, as funds permitted, the Association might undertake the preparation of quantitative crop forecasts and also possibly propaganda work in foreign countries.

We endorse the suggestions offered by Mr. Howlett in Appendix III. We would, however, emphasize the importance of the Forest and Scientific lines of research being carried on at a single centre. We understand that Jubbulpore is likely to be selected as the site for forest research, and in this case we would prefer that the laboratory should be located at Jubbulpore rather than at Ranchi.

APPENDIX I.

TECHNICAL TERMS USED IN THE LAC AND SHELLAC INDUSTRY.

A.—English.

Brood-lac	...	...	Lac about to swarm and used for infecting host-trees.
Button-lac	...	...	Refined lac made up in button shape.
Fine	...	...	Term used for the better grades of shellac.
Garnet-lac	...	...	An inferior class of refined lac so called from its dark colour ; made up in thick slabs or shapeless lumps.
Grain-lac	...	...	Lac crushed fairly uniformly to about the size of a pea and washed free from dye.
Lac-dye	...	...	The colouring matter obtained from lac by washing with water.
Orange	...	...	A grade of shellac so called from its light colour.
Seed-lac	...	...	An ambiguous term synonymous with both grain-lac and brood-lac. Owing to this ambiguity it has not been used in this report.
Shellac	...	...	Refined lac stretched into thin sheets and then broken into small fragments. The term is also used generically to include all forms of refined lac.
Standard I	...	...	A grade of shellac just superior to TN.
Stick-lac	...	...	Crude lac in all its forms.
Superfine	...	...	The highest grades of shellac.
TN	...	...	Usually surrounded by a diamond ; a non-proprietary mark of low-grade shellac.

B.—Vernacular.

Antia	...	...	A bundle of brood-lac (Sonthal Parganas).
Arhatiya, Ardar.		...	A commission agent or broker who conducts stick-lac sales.

Ari	...	... Lac collected before the insect has swarmed ; it contains the insect remains and therefore the whole of the dye.
Athali	...	... See Nand.
Baipari, Paikar	...	... A wandering trader who buys lac from the cultivators.
Baisakhi	...	... The summer stick-lac crop excluding that from the Kusum tree.
Bakhari	...	... Stick-lac free from twigs.
Batri	...	... Synonymous with Baisakhi (Raipur).
Bhasmi	...	... Synonymous with Katki (Chattisgarh).
Bhatta	...	... The stove used for refining lac.
Bhilwaya	...	... The workman who stretches the refined sheets of lac.
Bichan	...	... Brood-lac.
Bihan	...	... Brood-lac (Orissa).
Bij	...	... Brood-lac.
Binda	...	... A bundle of brood-lac (Sonthal Parganas).
Biuli	...	... Stick-lac free from twigs and dirt.
Chalna	...	... A factory term for the process of sifting lac through a sieve.
Chaolapoka	...	... The larva of <i>Eublemma amabilis</i> (lit. "a grain of rice").
Chaori	...	... Grain-lac.
Chapra	...	... Shellac.
Charki	...	... Windlass for twisting the shellac bags.
Charna	...	... The basting implement used by the Karigar.
Chatki	...	... A stone mill for grinding lac.
Chaulia, Chawali	...	... Lac on the stick (Orissa).
Chilwan	...	... Lac removed from the stick by scraping.
Chuchia	...	... The Hindi synonym for the Urdu "phunki."
Dalal	...	... A broker.
Dal-lac, Dali	...	... Broken stick-lac about the size of large peas.

Danri	...	... The stiff rod into which the shellac bag hardens after it has been twisted up in the melting process.
Dhanna	...	... A wooden block used in melting lac to guide the bag to fire.
Dom	...	... Shellac inferior to TN.
Dongi	...	... The flat, smooth stone in front of the stove in a shellac factory.
Ekraya	...	... Fine unwashed grain-lac.
Gada phunki	...	... Phunki lac from which the insect emerged in the godown (Raipur).
Garuhan	...	... Late phunki Katki (Raipur).
Ghasandar	...	... Literally "one who rubs"—The workman who washes grain-lac.
Ghonghi	...	... See Pank (Imamganj).
Gulla	...	... A factory term for lac still adhering to the stick.
Halorna	...	... A factory term for the process of hand-picking lac.
Hartal	...	... Orpiment ; yellow sulphide of Arsenic.
Imamganj	...	... A manufacturing centre in Gaya district. The word is used for a poor grade of TN shellac.
Jethwi	...	... The summer crop of Kusum lac.
Juri	...	... Brood-lac tied up in a tree.
Kachha Chaori	...	... Unwashed grain-lac.
Karchhula	...	... Shovel used by the Karigar for trimming his fire.
Karigar	...	... The shellac maker.
Karola, Kuni	...	... Small-sized grain-lac.
Karuan	...	... Early Katki or ari Katki (Raipur).
Katki	...	... The winter stick-lac crop from trees other than Kusum.
Katula	...	... Stick-lac full of twigs (Chota Nagpur).
Katwan	...	... Stick-lac removed from the twigs by pounding.
Ketka	...	... Kusmi lac, winter crop (Manbhum).
Khadi	...	... Biuli lac.

Khadi ...	... Brood-lac (Sambalpur).
Khari ...	... The twigs in stick-lac (c.f. Bakhari).
Khathi, Khathia ...	... Biuli lac (Orissa).
Kiri, Phog ...	.. Refuse remaining in the bag after lac has been melted out.
Kirkhodni ...	... The gouge used by the Karigar to slit shellac bags for the removal of kiri.
Kula ...	... A tray used for winnowing grain-lac.
Kuni ...	... See Karola.
Kusmi, Nagoli ...	... The winter stick-lac crop from the Kusum tree.
Lactora, Lahi ...	... A lac cultivator.
Lakh ...	... Lac.
Lakhwa ...	... A lac cultivator.
Lakhera ..	... A lac-growing plot.
Loka ...	... Lac on the stick (Raipur).
Lora ...	... Brood-lac (Raipur).
Magasur ...	... Kusmi lac (Raipur).
Minjana ...	... A single washing in the process of cleaning grain-lac.
Molamma ...	... The fine lac, mixed with dust, obtained by winnowing grain-lac.
Nagli, Nagoli ...	... See Kusmi.
Nand, Athali ...	... A stone jar about $2\frac{1}{2}' \times 2\frac{1}{2}'$ with the inside serrated, used for washing grain-lac.
Nera ...	... A palm-leaf frond used for spreading molten shellac on the Pipa.
Paikar ...	... See Baipari.
Palasi ...	... Lac from the Palas tree.
Pank or Phak ...	... Scum collected from the first washing of grain-lac.
Panna ...	... A single sheet of stretched shellac,
Parsi ...	... Lac from the Palas tree.
Passewa ...	... Lac washed out of the melting bags by boiling with water and Fuller's earth.
Pathri ...	... A depression in the Dongi containing water.

Pera	...	... The portion of the melting bag in front of the fire.
Phal	...	... A factory term for lac cleaned of twigs.
Phirwaya	...	... The coolie who turns the windlass to rotate the melting bag.
Phog	...	... See Kiri.
Phunki, Phungi	...	... Stick-lac collected after the insect has swarmed from it.
Phuswa	...	... Phunki (Raipur).
Pipa	...	... The porcelain cylinder containing hot water on which the Karigar places the molten lac for the Bhilwaya.
Pirbanda	...	... Instrument used by the Karigar for removing molten shellac from the bag.
Rangbatti	...	... Lac-dye.
Rangeen	...	... Katki, or winter crop from trees other than Kusum.
Reh, Sajjimatti	...	... Fuller's earth.
Safa chaori	...	... Clean washed grain-lac.
Sagar	...	... Mixed stick-lac of all kinds (Nimar).
Sajjimatti	...	... See Reh.
Sona phunki	...	... Phunki lac from which the insect emerged in the forest.
Sup Tray for winnowing lac.
Tarashi Pruning.
Thaili Sausage-shaped bag in which lac is melted.

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APPENDIX III.

SUGGESTIONS FOR RESEARCH.

I have been asked by the writers of the Report to suggest a general "Scheme of Research" which might constitute a suitable programme for the work of a Lac Laboratory. It should be understood that the enquiries outlined below are merely the suggestions of a biologist who has devoted some attention to the study of insects; and indeed it is never possible for any one man, however gifted or presumptuous, to foresee the lines along which other men with original ideas may best advance our scientific knowledge of a subject, or to lay down the law as to the precise manner in which they should attack its problems.

Many people forget, or do not know, that what is officially known in this country as "Research" should really be considered as two practically distinct types of enquiry. One type of "researcher" must be born, while the other may be made. The first is the man with an original mind seeking new discoveries; he looks for unknown relations between things, invents ways of explaining known relations in some new way, or devises some fresh method of technique which shall reveal unsuspected facts and relations. Originality of method, thought, or outlook is the characteristic of his work. Work of the second type, on the other hand, does not require and is not characterized by originality, though it may demand technical skill and accuracy of observation. It consists mainly in description, in the collection of data, and the application of familiar laws and methods to particular cases.

Of these two types the first may be the more valuable, but the second is the more common, and is the only one that is amenable to direction and control. Only one man can direct or control *original* research, and he is the researcher himself; so that in "schemes of research" to be carried out under direction, we can hardly legislate for him, since he will work according to his own ideas and not according to ours; and in making a scheme, all that can be done (and all that is here attempted) is to select certain points where enquiry seems most likely to lead to practically useful results, and where it

will at the same time contribute to the building up of a coherent body of reasoned knowledge regarding the whole subject.

Lac is at present a valuable monopoly in India, with a demand that will probably increase; but it would be short-sighted to assume that the present favourable conditions must continue indefinitely, or that India's great natural advantages in the matter of lac production must necessarily safeguard her against all competition. In an industry of this sort there are two obvious directions from which competition may have to be faced. Either (as in the case of indigo) a substitute may be discovered sufficiently good and cheap to supplant the natural product, or (as in the case of silk) other countries may succeed in establishing the lac insect and may undersell India by the application of scientific knowledge and organization to their methods of production.

The position of the industry will be much strengthened if the possibility of future competition is recognized, and if arrangements are now made for carrying out such work as may be necessary for attaining increased efficiency in production and general economic stability.

Of the two stabilizing methods recommended in this Report, the Forest Department is carrying out the first, by the expansion of the area of departmental lac cultivation in Government forests, an area which has hitherto been practically negligible as compared with the total area of cultivation. In connection with this expansion it is proposed to create a certain number of "brood-farms" for the production of brood-lac and its sale at a reasonably low rate to local cultivators.

With respect to the second method (the establishment of some form of research organization) it is suggested that the trade might engage the necessary scientific officers and finance the work of a lac laboratory for a suitable period. These officers would work in close touch with the Forest Department, but in the interest of the trade.

Preliminary grouping of enquiries.—The processes to be investigated are those that convert the carbon dioxide of the air and the plant-sap rising from the ground into any one of the many forms in which shellac reaches the public. To be in a position effectively to control this chain of processes in the interests of the industry (which

is our ultimate aim) we want, in a general way, to know three things.

Firstly, the precise nature of each process in itself ; secondly, the way in which it depends on or is related to the processes that precede or follow it ; and thirdly, how each process is or can be modified to our desire by altering the circumstances under which it takes place. Further, as a means of enhancing nett outturn, it may be necessary to enquire into causes of loss at various points in the chain, and the means of checking it.

In carrying out this chain of processes three chief agents are involved : plants, lac insects, and men.

- (1) *Plants* extract from the soil and air certain substances that are then worked up into the more elaborate forms of "protoplasm," cellulose, starch, sugar, oil, tannins, etc., etc.
- (2) *Lac insects* suck up some of these products from plant and from them manufacture lac.
- (3) *Men* collect the lac, remove dirt and dye, and convert the resin and wax into shellac. The shellac may undergo some slight further manipulation to fit it for special purposes.

Men also assist the lac insect by "lac cultivation" to find suitable and sufficient food in successive generations.

It will be obvious that the central and crucial process is number (2), and one group of enquiries will be those concerned with the insect, with the way in which it makes its lac and the nature of the raw materials it uses, with methods of increasing its output and checking loss from enemies or other causes. A second group will be those enquiries concerned with the plants that supply the insect with its food and raw materials particularly with regard to the conditions most favourable to their growth, the best practical methods of growing them for lac production, and the means of obtaining from them the greatest yield of raw material without undue detriment to their vitality.

On the results of these two sections of enquiry almost all improvements in general methods of lac cultivation in the field will depend. We have, therefore, no good reason for any separate group of enquiries under the head of "cultivation" but we have still to deal with the highly important processes of "manufacture" which are certainly

deserving of special enquiry. These processes, however, have already been made the object of investigation by various firms and individuals; a number of patents for particular methods or apparatus have been issued, and work in various directions is still in progress.

It is probably advisable to leave this section of enquiry to those who are already engaged in it, and who have spent no small amount of time and money in its pursuit. With a closer linking up of interests it might at some future time be possible to suggest for the common good a somewhat closer co-ordination of these scattered efforts, but for the present it seems best to concentrate attention on the biological and physiological study of the sources of supply, the insect and its food-plant, rather than on the chemistry and technology of manufacture.

If then we assume that research may for the time being be practically restricted to the insect and the plant, and that it is to be carried out partly in a laboratory run by a Lac Association and partly by officers of the Forest Department working in concert with the Association, the general arrangement of work might be very simple. The Lac Laboratory would undertake all work on the insect, the physiology of lac production, and the insect's enemies and parasites. The work undertaken by Forest Officers (excluding that of a more immediately practical nature) would include the general study of the "host" plants, but would deal especially with the most economical methods of utilizing a given plant as a continued source of raw material for lac production.

Though not closely connected with "research", the question of a crop forecast may here be touched on, as it is one of considerable importance. The establishment of reliable machinery for such a forecast would presumably be correlated with the gradual expansion of forest cultivation and with the increase in the number of "brood-farms", whose periodical reports would probably afford the safest basis for computing the average condition of the crop in their particular areas, if an arrangement could be come to whereby such reports could be furnished for the information of the Association.

If we may assume effective collaboration between the Forest Department and the Association, a definite division of labour between them in the matter of research will not only economize time and effort, but will also avoid competition or controversy. Both

competition and controversy are excellent things in their way, but in the early stages of tackling a complex subject they are too apt to mean waste of energy on unsound work and "eye-wash". In what follows I have taken it for granted that effective collaboration exists and that a reasonable division of labour is therefore practicable.

Staff and Equipment.—A staff might be engaged in the first instance for a period of five years. Appended is a list of the posts recommended, and a rough estimate of initial and recurrent expenditure involved in the maintenance of a Lac Laboratory on a suitable scale. If the success of the work justified it, some enlargement might be considered advisable at a later date.

Staff and Salaries.	Initial.		Annual Re- current.
	Rs.		Rs.
1 Laboratory Director on	1,500—2,000	...	21,000 (average).
1 Entomologist	500—750	...	7,500
1 Chemist	500—750	...	7,500
1 Physiological Assistant	400—600	...	6,000
1 Entomological "	300—500	...	4,800
1 Chemical "	250—300	...	3,300
1 Botanical "	250—300	...	3,300
1 Superintendent	150—200	...	2,400
1 Artist-Photographer	150—200	...	2,100
1 Head Fieldman	150—200	...	2,100
1 Fieldman	100—150	...	1,500
1 "	75—100	...	1,050
1 Laboratory Keeper	50—75	...	750
1 Stenographer	150—200	...	2,100
1 Clerk and Recorder	100—150	...	1,500
1 Typist	75—100	...	1,050
Menials and subordinates	150	...	1,800
			<hr/> 69,750
BUILDINGS			
Laboratories, Offices, Stores, Museum, and Insectary	24,000	...	...
Furniture, almirahs, racks and shelving, boxes and insectary fittings, museum fittings	6 500	...	1,000
	<hr/> 30,500	...	<hr/> 1,000

Staff and Salaries.	Initial.		Annual Re-current
	Rs.		Rs.
MATERIALS AND APPARATUS.			
Microscopes and lenses	3,000	...	300 (average).
Chemical and Physical	4,000	...	1,500
Glass and biological apparatus, reagents, stains, spirit, and microtome outfit ...	3,500	...	1,500
Photographic and micro-photographic outfit, projection apparatus, and artist's material	1,750	...	500
Tools, insectary apparatus, fees to specialists, and miscellaneous laboratory expenses ...	750	...	500
	13,000	...	4,300
Printing and minor publications	250	...	500
Books, Postage, Stationery, Repairs, and Sundries	2,000	...	1,000
Motor car, chauffeur, and upkeep	4,000	...	1,750
Travelling allowance of Staff ... ..	...	...	6,000
Total Initial Expenditure	49,750	...	...
„ Recurrent „ ... ..	...	...	84,300

It will be seen that the cost of site, necessary roads or paths, and of water, gas, or electric supply have all been omitted, as they vary so much with local conditions. For the same reason no estimate has been made of the cost of house-rent allowance or quarters.

Location of Laboratory.—The cost of the laboratory building has been kept at a low figure, because an impressive exterior is less important than equipment and location. I consider that the most important points in deciding its position are (1) that it should be in a lac-growing area, though not necessarily in a forest; (2) that it should be if possible in a climate sufficiently temperate to permit of critical laboratory operations (such as section-cutting) being performed without inconvenience all the year round; (3) that it should be within reasonably easy reach of the headquarters of the industry in Calcutta.

The writers of the report suggest Jubbulpore as a suitable locality, and at present this is certainly the best centre for the study of the departmental development of cultivation in Government

forests. As a centre for research, however, Ranchi is probably superior, and I therefore suggest it as one of the very few localities that meet the three above-mentioned requirements. Forest Officers concerned with lac development should of course be given every facility for visiting it.

Nature of Work.—An outline of what might be the main enquiries carried on is herewith appended.

A.—WORK ON FOOD-PLANTS.

1. Distribution of the main food-plants and the optimum conditions for their growth, especially with reference to climate, altitude, and soil.

2. Comparison of the amount and quality of lac got by equal inoculation of different species of plant with insects of the same brood.

3. Comparative resistance of different species of plants to heavy inoculation; decrease in yield and period necessary for recovery. (With this is connected the practical working of rotation systems such as that suggested in Chapter V of the Report.)

4. Possibility of more concentrated or intensive cultivation of food-plants, with special reference to the introduction of crop cultivation as in the case of arhar in Assam; or bush cultivation as with mulberry for silk-worms.

5. Effect of transference of insects from one species of plant to another, regarding yield and quality of lac and vitality of insect.

6. Relation between periods of greatest metabolic activity of the plant and of lac production by the insect. Means of artificially stimulating the plant's production of food-stuffs or raw material used by the insect.

Most of this section of the enquiry would be suitably carried out by Forest Officers, and little or no laboratory work is involved.

B.—WORK ON PARASITES.

1. The identity of the various parasites and enemies of the lac insect. Their geographical distribution, seasonal prevalence, and relative importance.

2. The general life-history of each parasite and its relations with the life of the lac insect. The relative amount of loss sustained

in different areas from the attacks of parasites. Correlation of parasite abundance with climatic or any other conditions.

3. Determining whether or not the various parasites have "alternative hosts" other than the lac insect. Dr. Imms' scheme is as follows: that an isolated area should be planted with lac, only one crop (Katki) being taken in the year; brood-lac for inoculation would be brought in each year for say three years from some locality relatively free of parasites. The amount of parasitic attack would be carefully watched; if it remains slight throughout, the lac insect is probably the only host of the parasites concerned; if it increases, the lac is probably being infected by parasites reared on other hosts in the neighbourhood.

4. If alternative hosts are present, the possibility of destroying the parasites through destruction of the alternative host at certain seasons.

5. Period of late emergence of parasites and utility of measures such as fumigation.

6. Determination of the relative severity of parasitic attack on lac of different varieties or from different food-plants.

7. Determination of the means whereby the parasites discover the lac insect at the particular stage in its career when they are accustomed to infect it. If by the smell of the lac, can the odoriferous substance be isolated and used as bait to destroy them? Are repellent sprays practicable?

8. The discovery of "hyper-parasites" and other enemies of the parasites; the possibility of using them as means of defence.

9. Using all facts obtained to help in devising methods of evading, repelling, trapping, disabling, or destroying parasites.

C.—WORK ON THE LAC INSECT.

(a) *Entomological.*

1. Study of the external structure of insects from different localities and food-plants, to ascertain the existence or otherwise of definite morphological species or varieties.

2. Study of the life-history of the insect, with special reference to the period of emergence in different localities, and the influence thereon of temperature, humidity, altitude, and food-plant.

3. Definition of the limiting and optimum conditions for the insect, especially temperature, moisture, and altitude; the relation between this optimum and that for different food-plants.

(b) *Genetics.*

4. The course of development of eggs and young; variations in fertility, and influence on fertility of different food-plants and climatic or other conditions.

5. Selective breeding, and the extent to which yield and quality may be improved by the distribution of pedigree stock.

6. The possibility of three-brooded varieties and the extension of their cultivation (with special reference to the introduction of crop cultivation, for which a three-brooded variety would be very suitable).

7. If the existence of a three-brooded variety is confirmed, or other definite varieties exist, the possibility of hybridizing or crossing varieties on Mendelian lines for the creation of new forms of greater productivity, fertility, or hardiness.

(c) *General Physiological.*

8. In connection with hybridizing, the invention of methods for rearing insects individually under observation.

9. Invention of any methods for rearing insects on a more intensive and concentrated scale as is done, for instance, with silk-worms.

10. Study of the reactions leading to swarming and to fixation (*i.e.*, variations in "heliotropism," "chemotropism," etc., in the insect's early stages).

11. Definition of the qualities or characteristics which determine the insect's preference for particular food-plants or which render a plant suitable for its food; determination of the qualities or characteristics which render it unsuitable.

(d) *Physiology of Lac Production.*

12. The structure of the lac-secreting glands.

13. The course of development of the glands in the life of both sexes.

14. The products secreted by the different glands, and the variation in these products (if any) with the age of the insect.

15. The variation in these products with the food-plant.
16. Micro-chemical methods of distinguishing these products (*e.g.*, by intra-vitam or *post-mortem* staining, etc.).
17. Variation in the amount of particular products caused by special treatment of the food-plant, as by watering, manuring, or injection with chemical substances.
18. Variation in products caused by alterations in temperature, humidity, or other physical conditions.
19. Correlation of the results obtained under foregoing headings and formation of working hypotheses regarding the process of formation of lac.
20. Experimental testing of hypotheses; practical application as a means of increasing production and controlling quality.

D. CHEMICAL AND MISCELLANEOUS.

1. Analysis of substances present in good food-plants and comparison with those in bad ones, with respect to those likely to serve as food or raw material for lac insects.
2. Analysis of lac from different food-plants and at different stages in the insect's life.
3. The same with special reference to the amount of wax and dye.
4. Removal or recovery of wax from special varieties of lac or kiri.
5. Testing and comparison of physical properties of lac from different food-plants, and the relation of these results to those got by analysis.
6. Preparation of artificial food-stuffs for the insect, in connection with headings C 8 and 9.
7. The general utilization of results in devising improvements in cultivation and securing better quality or increased yield with more security, less trouble, or less expenditure.

The collection, filing and indexing of all obtainable information, which should be available for the use of accredited enquirers.

Correspondence with Forest Officers, specialists, and others.

The submission to the Association of such reports as might be agreed upon, and the publication of results subject to the Association's veto.

APPENDIX IV.

LOCAL NOTES.

Sonthal Parganas.

This district, together with the adjoining areas in the Murshidabad and Malda districts of Bengal, presents somewhat of an anomaly as a lac-growing area, on account of its low altitude, most of it being below 600 ft. The reason why lac is found at this level is not definitely known. All that can be said is that the favouring rains of the cold weather are usually well distributed in the Sonthal Parganas, while the dry west winds of the open season, which are always adverse to lac cultivation, are not prevalent.

Lac is found in two fairly definite areas, the Dumka area and the Pakaur area. The former is nearly all Palas, and lies west of and just including Dumka. The Palas tree is quite common throughout the area, and usually occurs on open cultivated land. Dumka is the central bazaar and there are subsidiary bazaars in Haripur, Kumrabad, Jarmundi, Nunihat, Kangatta, Lakkapalasi, Barahat and Dumaria. It is said that this area used to produce annually some 10,000 maunds of lac, but hardly 1,000 maunds have been produced in recent years. The cause of the decrease is said to be the famine of 1916.

The principal dealers in Dumka are:—

Girdari Lal Marwari.

Ganpat Marwari.

Mahadeo Lal Marwari.

Jai Narayan Sahu.

Silochan Sahu.

Rameshwar Marwari.

There are two factories in Dumka, four in Nunihat, two in Jarmundi and two in Haripur; although small and unimportant, they are capable of refining between them the whole of the lac now produced in the Dumka area.

Pakaur is the centre of a very large lac area on the other side of the district and also taps very important areas in the adjoining districts of Murshidabad and Malda. In the Sonthal Parganas most of

the Pakaur lac is grown in the Pakaur sub-division but extends also into the Rajmahal and Dumka sub-divisions. The principal—almost the only—tree on which it is grown is Ber, and local trade recognizes three qualities according to soil :—

1st quality Pahari lac grown on the hills.

2nd quality Bagri lac grown on black cotton soil.

3rd quality Rahi lac grown on Laterite.

These varieties are purely local and the differences are slight. An interesting local report is that Pahari lac is not allowed to reproduce itself but is always grown from Bagri brood ; this requires confirmation. Lac is generally cultivated in homestead lands, on trees apparently planted originally for the sake of their fruit. The system is to retain one tree in ten for brood and to collect the balance as *ari* lac. The land is all under zamindari settlement and for the purposes of the Tenancy Act in the Sonthal Parganas lac has been defined as a fruit, so that tenants are entitled to its free use within their holdings. For other trees zamindars collect revenue by trees (2 or 4 annas per tree) or by area, but custom varies greatly. In the settlement of 1912, the rights of zamindars to collect this revenue were registered, and many trees were cut down by the tenants in an attempt to destroy landlords' rights over them. Ber coppices well, however, so that there has been no permanent loss.

Cultivation by tenants is often financed by the local merchants (mahajans) and the raiyats are frequently heavily indebted on this account, particularly the Paharias, who always grow their lac from imported brood.

Pakaur is the principal market and in a good year about 75,000 maunds of Baisakhi and 20,000 maunds of Katki pass through, but probably three-quarters of this amount is brought in from outside the district, mainly from Murshidabad and Malda, but also from Purnea and other districts north of the Ganges. A small quantity is also brought in from Nepal State (from near Biratnagar). Subsidiary markets are Hiranpur, Litipara, Amrapara, Kotalpakaur in the Sonthal Parganas and Jangipur, Dhulian, and Berhampur in Bengal.

The principal dealers and buyers in Pakaur are :—

Hiralal Jabulal.

Thakur Pd. Kalicharan.

Kanhai Lal Onkar Nath.

Rameshar Prasad.

Munshi Md. Ali.

These men are also mostly manufacturers or interested in factories, of which there are three large (30—40 stoves each) and eight smaller. There are also five small factories and one large one in Kotalpakaur. A large quantity of stick-lac is exported to factories in Calcutta and elsewhere.

The hilly portion of the centre of the Sonthal Parganas forms a large Government Estate—the Damin-i-koh (the “edge of the hills”)—and in this there is opportunity for Government action in the supply of brood-lac and in demonstrating to neighbouring zamindars up-to-date methods of propagation, pruning and collection. Lac is already grown in this area largely by Paharias, and the Forest Department collects a royalty of Re. 1-4-0 per maund of lac sold in the bazaars. The cultivators are generally heavily indebted to the mahajans who supply them with brood-lac and take two-thirds of the crop. Government has tackled the difficult problem of indebtedness by establishing throughout the Damin-i-koh grain *golas* from which seed is advanced to the tenants and recovered with reasonable interest at harvest time. With this machinery already in existence, much might be done to set the lac industry on an improved footing. The local Forest Department might be responsible for the production and distribution of brood-lac, against which recoveries of cleaned stick-lac would subsequently be effected. A start might be made at Hiranpur and Amrapara.

The Government Forests, and the whole of the Damin-i-koh, are said to contain numbers of Kusum trees, but it is very doubtful whether the numbers within a reasonable area are sufficient to make it worth while attempting to introduce the cultivation of lac on them. They have not been cultivated up till now and success is doubtful owing to the unusual climate. An experiment would, however, be interesting and would give useful data even if it did not actually succeed. At present the raiyat does not realize the value of Kusum as a lac producer, and many of these trees are cut for sale as timber and firewood.

The Dumka Palas area is wholly outside the Government Estate. An area containing Palas trees near Dumka might be acquired and

managed by the Forest Department for demonstration purposes and for the supply of brood-lac.

BIHAR.

Small quantities of lac are produced throughout most of the Bihar districts, but it is doubtful whether its cultivation is capable of much extension. Palas and Ber are found in parts of the area, but the climate appears to be far from favourable, particularly in the cold weather, and, though the production is undoubtedly capable of expansion, the possible total is not likely to be sufficient to warrant any special measure.

At present, a certain amount of lac is marketed annually at Chapra and some also arrives at Pakaur from Purnea and adjacent districts. In both cases the totals are, however, quite small.

GAYA.

The importance of Gaya district lies chiefly in the shellac manufacture carried on at Imamganj (including Raniganj), a village lying in the angle of country between Hazaribagh and Palamau districts. Lac is grown in this area, and along the southern border of the district. A small quantity is produced near Daudnagar on the Sone river, and in other parts of the district.

The methods of cultivation employed are similar to those in Chota Nagpur but are rather more primitive. Important cultivators are :—

Akhbar Hussain Khan of Kothi, P. S. Imamganj.

The Raja of Kunda (Hazaribagh), Proprietor of Raniganj.

Abdul Kadir Khan of Malhari, P. S. Imamganj.

Abdul Rahman Khan of Malhari, P. S. Imamganj.

Chhatardhari Sahu of Bihopur.

Jagu Singh and Nagesar Singh of Jamuna.

Sharafat Khan of Kothi, P. S. Imamganj.

Imamganj is the only market of any importance. It appears to receive about 40,000 maunds of Baisakhi, 20,000 of Katki and small quantities only of Kusmi and Jethwi. Much of this lac, however, comes from adjoining areas in Palamau and Hazaribagh districts, and Gaya district itself produces 25,000 maunds annually.

There are twelve factories at Imamganj (including Raniganj) and one each at Sherghati and Mathurapur. The largest manufacturers are:—

Janki Lal Seth.
Ganga Ram Jai Narayan.
Bishan Sahu Baldeo Ram.
Ajediya Sahu (Sherghati).
Bishan Sahu Sri Ram.
Bhagwan Das.
Pragsau Govind Lal.
Behari Sahu, son of Deoram.
Ishardass, son of Ramnarain.

The total number of stoves is in the neighbourhood of 150, so that the annual possible outturn is about 30,000 maunds of shellac. The manufactured shellac is carted by road to Gaya and thence railed to Calcutta.

Imamganj is chiefly notorious for the poor quality of the shellac manufactured. In fact "Imamganj" is tending to become in Calcutta a definite name for a grade of shellac below TN. There is no reason at all for this, other than carelessness on the part of the manufacturers and the crudity of their methods. It is hoped that the revision of the Calcutta buying contract and the penalties imposed on adulteration will go a long way to rectify this state of affairs.

HAZARIBAGH.

Almost all the lac produced in this district comes from the area lying south-west of the Grand Chord Railway Line; and lac can be grown over most of this area, although at present the majority comes from the northern and western portions of the Chatra subdivision. Cultivation can be extended almost indefinitely, particularly in the neighbourhood of Ramgarh. The greater part of the lac is grown on the Palas tree, with Ber a bad second and Kusum a worse third. Kusum is quite a common tree and used to be more extensively infected than it is now. The cause is said to be the almost complete failure of the Kusum crop some years ago, and the consequent impossibility of obtaining Kusum brood. The local authorities are alive to this emergency and proposals are being framed to meet it.

There are no Government Forests in the lac area and as cultivation is mostly on Palas, it is usually met with, not in homestead but in waste lands. The zamindar is sometimes considered to own the right of cultivation, but in many cases tenants have succeeded in establishing a customary right. Where the zamindar's right is established, he usually grants small leases for cash or for a share of the produce. Cash leases are usually for long terms, nine years being a common period. Produce leases are of two kinds. If the lessee is a Kamia (*i.e.*, practically a serf of the zamindar) the custom is for the landlord to provide the brood and finance the business. He takes all the crop except one-eighth which the Kamia receives as his share. On the other hand the better class of tenants are naturally able to hold out for better terms, and their lease is usually on a basis of three-fourths of the yield to the zamindar and one-fourth to the tenant, the brood being provided by the zamindar or cultivator according to their relative business acumen. Cash rents have become more popular of late years particularly with absentee landlords.

Lac is usually collected by Baiparis, but zamindars have realized the profit to be made on this side of the business and some of them, particularly where produce leases are common, take the whole of the lac and credit the cultivator with his share against his land rental or against advances of grain or other commodities.

The stick-lac finds its way eventually to Chatra market or to Imamganj (Gaya district), Ranchi or Jhalda (Manbhum); there are smaller markets at Hunterganj and Sherghati. With so much of the produce marketed outside the district it is impossible to say how much is grown within it. In a good year the Chatra market probably deals with 20,000 maunds Baisakhi and 10,000 maunds Katki. It is quite impossible to estimate the crops from Kusum, but they may easily be of considerable importance.

Some lac from this district also finds its way to Daltonganj, Lohardaga and Hazaribagh.

The largest cultivators of the district are :—

Irshad Ali Khan, of Bhadia (Gaya district)

Khirodhar Sahu of Chatra

Mither Nichaundhia of Amarut (Gaya)

Doman Nichaundhia of Chatra.

The largest dealers in Chatra are :—

Hari Baksh Seth, Marwari

Sowa Lal Seth

Bansi Lal Agarwala.

There are two small factories in Chatra belonging to :—

Hari Baksh Seth

Sowa Lal Seth,

but neither is large enough to be really important.

Hazaribagh district is most favourably situated for Government action to improve the lac industry, as the greater part of the lac-growing area is in the Ramgarh Court of Wards Estate. The selection, and if necessary the acquisition, of areas for brood farms and the introduction of machinery for the distribution of brood, etc., should not be difficult.

PALAMAU.

Palamau is one of the most important lac districts, being second only to Manbhum. Most of the lac grown is on the Palas tree, patches of which are a common feature all over the district. Very little lac is grown on Ber or Kusum, though the latter is a common tree in the more heavily wooded and hence more sparsely populated parts of the district. The reason why Kusum is not much cultivated is because it is a tree of the forest and not of the open country, and also because it is never gregarious. Its cultivation requires considerable care and attention, and hence is unpopular despite the fact that it yields a larger quantity and better quality of lac than Palas. Further, Palamau is a field for the recruitment of coolies for the tea districts. Labour is thus not so plentiful as it would otherwise be, and, what there is, is fully employed in agriculture. Hence there is practically no chance of lac cultivation being developed except in suitable areas within easy reach of existing villages.

The Palamau zamindars claim all rights over trees capable of producing lac, and this is frequently their chief source of income. They usually make a simple verbal settlement with their raiyats from whom they secure as high a rate as possible; four annas per tree is a common rate. In addition, many zamindars auction to Baiparis the rights of collection within their estates. Whether the zamindar helps the Baipari to enforce his monopoly or not, is a risk which the latter must face; and, on the whole, this method of sale is not usually

very remunerative. In Government Estates it was decided in 1916 that trees standing in cultivated areas should not in future be assessed for lac; trees growing in unoccupied lands are leased at from one-half to one anna per tree.

The principal markets in Palamau are Daltonganj and Garhwa. At these towns are marketed most of the lac from the Dudhi area (south of the Sone river) of Mirzapur district and also small quantities from Sirguja State and Hazaribagh district. On the other hand a small quantity of lac from Palamau goes direct to factories in Imamganj (Gaya).

The principal Arhatiyas in Daltonganj are:—

Mahabir Prasad
Bhui Ram of Shahpur
Kedarnath Surajmal
Nand Kishore Misria
Teka Pande

And in Garhwa :—

Nanku Ram
Ghasi Ram Baldeo Dass
Kedarnath Sahu (of Rehala).

With a good crop the yield would probably be:—

				Baisakhi.	Katki.
Daltonganj	...	...	...	30,000	15,000
Garhwa	...	...	...	40,000	20,000

but a small and varying quantity of Kusmi and Jethwi, up to 300 and 1,500 maunds, respectively, is also sold.

The greater part of this lac goes to Mirzapur, and Palamau is the most important source of stick-lac supplies for Mirzapur. The larger manufacturers retain agents in the district and numbers of dealers visit Daltonganj and Garhwa as the crops come in. Proposals have been prepared by the Forest Department, and are under consideration by the Local Government, to acquire a suitable area under Palas near Daltonganj, for experiment and demonstration purposes and for the supply of brood-lac. There is scope for an experiment of this kind and it is hoped that its success will be such as to encourage

the development of similar demonstration areas in other parts of the province. The experiment would appear to have greatest chances of success if the areas thus taken up could be notified as Reserved Forest. The chief difficulties will arise from theft and also from the scarcity of labour, but these will doubtless be overcome by the provision of forest guards and other adequate staff, and by the selection of sites where labour is available. The existing Government Forests are extensive, but are remote from more populous areas, so that labour is scarce, and they would not be so suitable as centres either for demonstration work or for the supply of brood-lac.

RANCHI.

Lac is found over the whole of Ranchi district and is brought into small bazaars throughout the area. The district, which is situated on a plateau about 2,200 feet above sea-level, enjoys an equable climate and comparative immunity from severe frost. It is thus in every way suitable for lac cultivation, while at the same time there is plenty of scope for development. Kusum trees are common throughout the district, although at a rough estimate probably not more than five to ten per cent. of them are at present cultivated. Ber is also common and so is Palas, particularly around Muru on the Chaibassa road.

The principal markets are Ranchi, Bundu, Lohardaga, Khunti and Mananghatta, while a considerable part of the crop in the north-east of the district finds its way direct to Jhalda and Balarampur in Manbhum district.

Good crops under present conditions would be :—

					Maunds.
Kusmi	...	...	...	...	20,000
Jethwi	...	...	...	...	10,000
Baisakhi	...	...	...	...	35,000
Katki	...	...	...	...	20,000

excluding that portion which goes direct to Jhalda. These figures have not been reached within recent years. The possibilities of the district are great, however, and there is no doubt that, if conditions of price and weather are favourable, the above figures could be doubled without much difficulty.

The relations between zamindar and cultivator are the same as in Manbhum, and cultivation is practically always by small holders. Manufacture is not highly developed as yet, and most of the stick-lac is exported to Jhalda and Balarampur in Manbhum for manufacture.

There are, it is true, two large factories in Ranchi belonging to Rai Sahib Thakur Das and Rang Lal Sahu respectively. The former has about 45 working stoves ; the latter about 70. Rai Sahib Thakur Das has also a branch factory at Muru. Besides these, there are only a few small factories in Bundu. As one would expect from a district producing quantities of Kusum lac, the grades manufactured are largely fines and superfines of private marks, both in the form of orange shellac and button-lac. The district presents an excellent opportunity for the extension of manufacture. Communications are fairly good and Ranchi and Lohardaga suggest themselves as suitable localities for factories.

Government assistance in the extension and improvement of cultivation is most desirable. The field is large, but unfortunately sufficient local knowledge has not been obtained to make it possible to suggest definite areas for brood farms, although the neighbourhoods of Bundu, Khunti and Lohardaga appear to be suitable.

MANBHUM.

Manbhum is the biggest and most important lac-producing district in India. Lac is grown throughout the district, but chiefly in the western and southern portions of the Sadr sub-division in thanas Chas (west), Jhalda, Baghmundi, Ichagarh, Chandil, Barabazar, Bandwan and Manbazar. The important centres of the lac-growing area are Balarampur (Barabhum), Jhalda, Chas, Manbazar.

A small quantity is also collected in the north of the Dhanbad sub-division with centre at Gobindpur.

The principal host-trees are *Schleichera trijuga* (Kusum), *Zizyphus Jujuba* (Kuli, Ber or wild plum), *Butea frondosa* (Paras or Palas), but lac is also grown in small quantities on *Dalbergia latifolia* (Satse), *Ficus* spp., *Ougeinia dalbergioides* (Pandon) and many other trees.

Cultivation is more intense in this district than anywhere else in India. The methods are, however, not much more advanced. The ease with which Ber can be grown and the quality of its lac crops have led to a certain amount of artificial regeneration of the species. The clumps of Ber round the village sites are a feature of this landscape and in some cases gardens (*baris*) have been given up entirely to its cultivation. Very occasionally regular plantations of Ber up to an acre in extent are to be seen. The trees on a tenant's holding

are generally considered his own and he pays nothing for the right to cultivate. Zamindars lease out the trees growing in forests and waste lands at a few annas per tree according to size and species.

The principal stick-lac markets and the crops of clean stick-lac in maunds to be expected in a good year are as follows :—

Market.	Kusmi.	Jethwi.	Baisakhi.	Katki.
Balarampur	12,000	5,000	25,000	10,000
Jhalda	25,000	8,000	45,000	16,000
Chas ... ..	...	...	10,000	5,000
Manbazar ... ..	...	...	20,000	6,000
Katras ... ..	...	...	2,000	1,000
Gobindpur ... ..	...	...	2,000	1,000

The Baisakhi and Katki crops in Balarampur and Manbazar are mostly from Ber ; in Chas, Katras and Gobindpur most from Palas ; and in Jhalda about equal quantities of Ber and Palas.

The bulk of this lac is manufactured into shellac within the district, though considerable quantities of stick-lac are exported to Calcutta and other manufacturing centres. A very large quantity of stick-lac is imported into Manbhum for manufacture into shellac chiefly at Balarampur and Jhalda. In a good year as much as 1,50,000 maunds of stick-lac are imported into Balarampur and 50,000 maunds into Jhalda. The bulk of this lac comes from Ranchi, Orissa and the Central Provinces. Large quantities are also imported by road into Jhalda from Hazaribagh and Ranchi districts, but the market figures above include these.

The principal stick-lac merchants and brokers are :—

Hukm Chand Hardit Ray of Jhalda and Ranchi

Mirzamal Marwari of Purulia and Jhalda

Jugalkishan Marwari of Purulia and Balarampur

Laxminarayan Gajhadhar of Balarampur

Khexidass Premdass of Balarampur

Nisikanta Banerji of Balarampur

and numerous others. These firms keep agents in most of the large and small bazaars and employ Baiparis who wander round the smaller

bazaars buying lac. They also send agents to the markets along the Bengal-Nagpur main line and to the Central Provinces at the time when the lac crops are coming into the markets. The method of sale of stick-lac in Jhalda is by open negotiation and in Balarampur and most other markets by the cloth method.

The following are the manufacturing centres showing number of factories, total number of stoves and possible daily output in maunds of shellac :—

Names.	Number of factories.	Total number of stoves.	Possible outturn in maunds of shellac.
Balarampur	27	400	300
Jhalda	15	150	110
Chandil	3	40	30
Chas	3	15	11
Purulia	3	40	30
Barabazar	2	25	18
Mitrah	1	10	7
Total	54	680	506

Working regularly, say 300 days a year, the factories in Manbhum district could turn out 1,50,000 maunds of shellac.

The principal manufacturers are :—

BALARAMPUR.

Hiralal Lalchand
Harnandan Rao Chuni Lal
Ratanlal Lunawat
Lachminarayan Surajmal
Surajmal Jiwanram
Baldeo Dass Surajprasad
Karikaran Bariram
Kakantlal Basantlal
Bechulal Baijula
Gajhadhar Jaydayal

Ramdass Bhagwandass
 Ganeshdass Baldeodass
 Ghasiram Nagarmall
 Ramdass Beharilal

JHALDA.

A. M. Aratoon
 M. C. Gregory
 S. J. Apcar
 Kasi Prasad Bhairo Prasad
 Atalbikari Haldar

PURULIA

A. M. Jordan

CHAS.

Ramdass Bhagwandass

CHANDIL.

S. P. Banerji

BARABAZAR.

Hari Kishendass, Marwari.

There is a small area of Government Protected Forest near Mahta. It is part of Chaibassa Forest Division and the lac is disposed of much as in zamindari areas; the total receipts, however, are only about Rs. 150 annually. The area is only important as a possible site for a Government brood farm as it is within easy reach of large lac-producing areas lying between Balarampur and Jhalda.

Manbhum, being the most important lac-producing district, calls for special action in order further to stimulate the industry. Several sites should be selected for brood farms, particularly one each in the neighbourhoods of Chas, Jhalda, Balarampur and Manbazar. No definite areas can be suggested but selection should not be difficult.

The manufacturers are fully alive to the importance of up-to-date mechanical apparatus, and in Jhalda and Purulia, where the industry is largely in the hands of Armenians, mechanical crushers and grain-lac washers have been installed and are giving satisfactory results. These manufacturers also show considerable enterprise in taking leases and propagating their own lac and experimenting with the formation of plantations of Ber.

SINGHBHUM.

Lac grows wild or is cultivated almost throughout this district. The principal species on which it grows are Kusum and Ber, but it also grows on Ruta (*Ougeinia dalbergioides*), Hesa (*Ficus Rumphii*), Lea (*Ficus glomerata*). Cultivation is in the hands of tenants, mostly of aboriginal races, who generally utilize trees (for which they pay no separate rents) on their home lands and gardens. For the cultivation of trees standing in village forests they pay two annas per tree to the village headman, who in Government Estates pays this amount into the treasury. When the lac crop is reaped the cultivators bring it into local markets and dispose of it to Baiparis, who practically rule the markets and are frequently agents of Arhatiyas and dealers in Chaibassa and Chakardarpur. The principal markets are at Chaibassa, Chakardarpur, Gamaria, Tatanagar, Jaganathpur and Jaintgarh. It is not possible to estimate the trade of each of these markets separately, but in a good year the total crops are about :—

						Maunds.
Kusmi	...	...	...	...	...	15,000
Jethwi	...	...	...	...	...	10,000
Baisakhi	...	...	...	...	...	30,000
Katki	...	...	...	...	...	25,000

The whole of this lac, however, does not come from Singhbhum district. About one-half comes from Mayurbhanj, Keonjhar and other Feudatory States.

The principal Arhatiyas and dealers are :—

Mithai Lal
 Hiralal, Marwari
 Jokhiram, Marwari
 Sashi Bishun Kundu
 Petambar Dalal
 Hari Pada Datta
 Kedar Datta
 Ram Kamak Datta
 Mangi Lal, Marwari.

Mithai Lal has a factory in Chakardarpur. Most of the lac from the district is sold to dealers and manufacturers from Balarampur.

The development of the industry in Singhbhum must depend largely on the action taken by the Forest Department, which controls extensive portions of the district, both as Reserved and Protected Forests, and at present obtains very little lac revenue from them. The question of allowing the cultivation of lac in the Protected Forests is worth raising, and, if direct cultivation by the Forest Department is not favoured, these forests might be thrown open for lac development by contractors or petty cultivators. The cultivation of the Reserves seems a possible source of income to the Department and it is suggested that the work be taken up departmentally as in Damoh. The possibilities of the Singhbhum district are great and the Forest Department of the Bihar and Orissa Government would seem to have an excellent opportunity of showing what can be done by improved methods, particularly as the Kusum tree abounds in all parts of the district.

ORISSA FEUDATORY STATES.

Of the twenty-four States, the following produce lac :—

Athmalik, Gangpur, Dhenkanal, Keonjhar, Baud, Mayurbhanj, Pal-Lohara, Kalahandi; other States produce only small quantities. Orissa is a Kusum area, and, as one would expect, the more hilly portions are those which produce the lac. Kusum is in every State the most important tree, followed by Palas and Ber and the *Ficus* species.

The following are crop estimates based on recent years' averages as supplied by local authorities :—

Maunds Annually.

Athmalik	...	50	(Probably much greater in normal years).
Gangpur	...	3,500	
Dhenkanal	...	450	
Keonjhar	...	160	(Probably much greater in normal years).
Mayurbhanj	...	1,800	
Kalahandi	...	2,100	
		<hr/>	
		8,060	

The above figures are all conservative and based on recent outputs which in most parts of India have been poor. A fair estimate is probably 15,000 maunds in a good normal year, and this with improved methods might easily be doubled.

The method of collection varies in different States. In Athmalik a lease is given to a monopolist who employs daily labour for

propagation, collection, etc. In Gangpur any one may buy lac, but must obtain a license costing Rs. 50 in order to do so. The State reserves the right to fix a minimum price. As a method of ensuring the State share of the revenue, this system is very suitable; and by encouraging competition, it secures a fair rate to the cultivator. In Keonjhar there is a monopoly lease on a royalty basis, but a minimum total annual payment to the State is fixed. In Mayurbhanj State a monopoly lease is granted. The State has an organized Forest Department which encourages the cultivation of lac. The markets for lac are the railway stations along the B.-N. main line, particularly Chakardarpur (including Chaibassa) for Mayurbhanj and Keonjhar, Raj Gangpur for Gangpur, Raipur (Rajim) for Kalahandi.

The industry is capable of much extension throughout the Orissa States, which might well produce more Kusum lac than any other area in India. This is the largest area remaining in India without any railway, but the Bengal-Nagpur proposed branch Raipur-Vizagapatam will pass through Kalahandi and should stimulate the industry there; while the Sini Branch across Singhbhum will also undoubtedly stimulate production.

The State Durbars are fully alive to the importance of lac as a source of revenue, and are taking steps to encourage production backed up by the State Forest officials, particularly those of Mayurbhanj. At present cultivation is only on trees near the villages, and is rarely found in the remote jungles.

BILASPUR.

Roughly the northern half of the district produces lac, the southern half being open cultivated land with very few trees. Small clumps of Palas are to be seen occasionally in the fields, but the total number is too small to be of importance. Most of the lac area is included in the large zamindaris of Matin, Uprora, Pendra and Korba, and the principal tree is Palas.

The only important market is at Pendra on the Bilaspur-Katni branch railway. Good crops are, in clean maunds :—

Kusmi	...	...	...	...	2,000
Jethwi	...	...	...	...	500
Baisakhi	...	...	...	...	20,000
Katki	...	...	...	...	10,000

Markets of less importance are at Bilaspur, Champa, Raigarh (Feudatory State) and Akaltara, and a market is developing at Kota. These markets together produce about half the yield at Pendra.

The principal dealers in Pendra are:—

Manik Ram Mahadeo, Marwari

Somaru Ram Rambaros

Sita Ram Kanaiya Lal

Alladad Imam Din

Madhu Rangnandan Prasad, agent of Kashi Prasad, of Jhalda and Mirzapur.

There are no very large suppliers to the market. Sales are usually by open auction based on the *chaori* content.

The lac actually grown in Bilaspur is probably half the Pendra yield, the other half coming from the Feudatory States of Sirguja and Korea.

Very little lac cultivation is carried on in Government Forest. There are three Ranges, two of which, East and West Lormi, are unworked for lac; the third Pantora being leased out to a contractor for a small sum. He, however, has too little capital to be able to undertake much by way of extensions. The work should be taken over departmentally in all Ranges.

The zamindari system usually means the sale of the monopoly to a contractor. The zamindars of Matin and Pendra have revenue stations where royalty on export is collected at Rs. 2-2-0 per maund.

The chief problem in Bilaspur, as in most districts, is the supply of brood-lac. The large zamindaris of Matin, Uprora and Korba might be encouraged to start lac nurseries and a beginning might be made with Pendra which is under the Court of Wards. One large Malguzar, Khushal Singh of Kargi near Tendwa, is now extending cultivation and can supply brood-lac in the west of the district.

RAIPUR.

The Mahanadi river roughly divides Raipur district into plain and hills. To the west is the plain, open, cultivated land containing little tree growth and of no importance as a lac-producing area. East of the Mahanadi the country is hilly and generally well wooded, and in this area is to be found the bulk of the lac grown in the district. In the northern portion, lac is principally grown on Palas and in the southern on Kusum.

The principal markets in the district are at Rajim, Dhamtari and Arang. Dhamtari has a very important feeder bazaar at Balod in the neighbouring district of Drug. The annual outturn from these markets is, roughly, in maunds of clean stick-lac :—

		<i>Kusmi.</i>	<i>Jethwi.</i>	<i>Baisakhi.</i>	<i>Katki.</i>
Rajim	...	20,000	10,000	2,000	2,000
Dhamtari (including Balod)	...	10,000	5,000	1,000	1,000
Arang	...	5,000	2,000	2,000	1,000

These bazaars are therefore important principally for the Kusum lac they produce. The total quantity is small, but is capable of almost indefinite extension as the Kusum tree is very common throughout the whole tract and in the Feudatory States of Kanker, Bastar and Kalahandi, all of which supply lac to these markets.

Communications are very poor within the district, but the proposed railway from Raipur to Vizianagram will open up much of the eastern part of the district and will pass through Arang. If the Rajim line is extended to the south-east, it will undoubtedly stimulate the lac trade.

Most of the lac-producing areas are in the hands of large zamindars who give out annual monopoly leases to contractors. The latter take no interest in cultivation, but buy the lac from the cultivators at pre-arranged rates.

The system of sale in the big bazaars is generally by negotiation, the seller hawking samples round to the various buyers and selling to the highest bidder. Sales are generally by the clean bojha of 12 maunds (1 lac maund = 16 standard seers). A bojha is therefore 192 seers or approximately $4\frac{1}{2}$ standard maunds. Discount for stick and dust is always considered in fixing the price, but a new bojha of 5 maunds and 10 chattaks is starting in Rajim which is supposed to consist of—

Clean lac	...	...	...	...	192 seers
Dust	...	...	...	...	4 "
Stick	...	...	...	...	4 " 10 ch.

The principal regular buyers are agents from Mirzapur, Jhalda, Balarampur and Purulia. These are generally central collecting

agencies, and each will have a system of sub-agencies ramifying through all the small bazaars where lac is brought in by contractors, Baiparis and cultivators. Important sellers in the district are :—

Dhamtari—

Jamnadass Pannalal

Naraindin Jagganath

Rajim—

Bansi Lal Amirchand, Contractor of Giriaband Estate

Gopi Kishan Multani, Contractor of Kalahandi Feudatory State (Orissa).

There is one small factory in the district at Rajim, owned by Mr. Lucas.

There are several zamindaris under management of the Court of Wards. Kauria has been so managed for many years and a fair outturn of lac obtained. No scientific methods are employed as the staff is small and untrained. Sales have generally been by contract either on the monopoly system to the highest bidder or by royalty, the contractor paying so much per maund of lac exported.

Government Forests are very large and concentrated in two compact blocks, one in the north and one in the south, each under a Divisional Forest Officer. In 1905, when the Forests were all under one officer, an attempt was made to work lac departmentally. To provide labour many forest villages were started, the inducements being that tenants should receive three-fourths of the lac crop and Government one-fourth. The system was worked for several years, but eventually failed about the time when prices fell in 1908-09. The officer in charge retired about the same time and the industry has never been seriously revived.

However, a number of very useful lessons can be learnt from the records of this experiment. An enumeration was made of Kusum trees fit for infection. Twenty thousand were enumerated in two ranges (Laon and Sirpur) and it was estimated that there were 1,50,000 trees in the whole division. If each tree is infected once in three years, 50,000 trees might with intensive working be infected annually. A large Kusum tree has been known to give five to six maunds of stick-lac and the average in a good season is probably one maund. It is obvious, therefore, that the possibilities were great. The records show that about 15,000 trees were infected in 1907-09 for the Kusmi crop. Unfortunately the crop was very poor owing

to adverse climatic conditions and the ravages of the predatory moth, *Eublemma amabilis*, and averaged only $3\frac{1}{2}$ lbs. per tree. The fates seem to have been against the Department throughout though it is also likely that, owing to the small size of the special staff entertained, the forests were largely at the mercy of lac thieves, who no doubt saw to it that the official yield was reduced to a minimum. The lac collected was sold by the local officials for Rs. 9-5-9 per 32 seers (or Rs. 11-11-2 per standard maund). At that time the Calcutta TN rate was Rs. 70 so that Kusum stick-lac at this period would be worth about Rs. 55 per maund. The lesson to be learnt is that unscrupulous middlemen may succeed in blocking competition at sales of Government stick-lac, and that such sales should only be held under the personal supervision of officers thoroughly acquainted with the market.

It is obvious that in the Government Forests of Raipur there is a very large potential supply of stick-lac which only awaits development. The local Forest Department is fully aware of this fact. Development will, however, require a well-trained staff and the system employed should be that which has proved so effective in Damoh, namely, direct departmental exploitation. The previous system was satisfactory so long as the cultivators' interest was retained by large profits. When a slump occurred in the market, and they got little return for their work, they naturally lost interest and successive crops were likely to fail. Had the work been wholly departmental, it would have continued, despite low profits, and the industry would have been ready for immediate extension as soon as the market recovered.

When the Forest Department has put the cultivation of lac on a secure footing, it will be able to supply brood-lac to outside cultivators in the neighbourhood. There are some parts of the district in the east and south-east which are 40 or 50 miles from the nearest forest, and it would be well to start brood farms in these neighbourhoods. No suitable places are known at present, but the Kusum tree is so common that areas could easily be selected. The big zamindars should be encouraged to form brood farms and Government might set the example in Kauria (Court of Wards) zamindari. The chief difficulties will be proper inspection and management, but with an adequate and efficient staff such as the project could well afford to maintain, these difficulties could be overcome.

CHATTISGARH FEUDATORY STATES.

The States fall into three natural divisions, north, central, and south, and contain very important lac areas ; they are still more important as potential sources of increased supplies.

The northern States, Changbhakar, Korea, Sirguja, Jashpur, Udaipur, Raigarh, Sakti, Sarangarh, and the central States, Kawardha, Chhuikhadan, Khairagarh, Nandgaon, are mainly Palas areas. The southern States, Kanker and Bastar, produce mainly Kusum lac. Subject to this generalization, both varieties come in varying proportions from all areas.

Yields are at present difficult to estimate, but the following is a fairly close, though conservative, annual estimate in maunds :—

			Kusmi.	Jethwi.	Baisakhi.	Katki.
Changbhakar	...	...	Very	little	at present.	
Korea	...	...	200	100	10,000	6,000
Sirguja	...	...	...	...	5,000	2,200
Jashpur	...	...	50	50	...	...
Udaipur	...	...	Very	little	at present.	
Raigarh	...	...	1,200	800	400	600
Sakti	...	...	Very	little	at present.	
Sarangarh	...	...	...	...	40	20
Kawardha	...	...	100	50	100	50
Chhuikhadan	...	...	Very	little	at present.	
Khairagarh	...	...	...	...	125	200
Nandgaon	...	...	10	10	20	20
Kanker	...	...	2,000	1,000	...	...
Bastar	...	...	500	200	...	...
Total	...	...	4,060	2,210	15,685	9,090

The important States are :—

Korea
Sirguja
Raigarh
Kanker
Bastar

though the remaining Feudatory Chiefs are also aware of the importance of lac and are endeavouring to stimulate the industry.

Korea.—Lac is produced everywhere except in the north and west of Kilhari circle and in Baghrondi circle ; that is to say everywhere except along the border of Changbhakar. The Durbar leases the right to cultivate in lots of a few villages. The principal local market is Baikunthpur whence the lac is exported to Pendra.

Raigarh.—The northern and hilly portion round Lailunga and Ghargoda produce Kusum lac, whilst immediately west of Raigarh town is the Palas area. The Durbar leases the right to collect a fixed royalty on exports of lac.

Sirguja.—There are four Tahsils in Sirguja State. Ambikapur produces a negligible quantity of lac, chiefly Kusum. The other three, Samri, Pal, and Chandni, are all full of Palas, and all produce quantities of lac. The system of leasing is by petty annual contracts. The principal dealers are Mahadeo Choudri, Jorisahu Hiralal, and Narainsahu, all of P. O. Ambikapur, Sirguja State.

Kanker.—Lac is produced throughout the State, which is a very important supplier of Kusum lac. The Kusum tree abounds everywhere. The State Forest Department is responsible for the control of the industry and every effort is made to stimulate it. The State share of the profits is obtained by the moderate export royalty of Rs. 6-4-0 per maund. The whole of the stick-lac, which is of the finest quality grown in India, is marketed at Dhamtari, where there is considerable competition for its purchase, chiefly among buyers from Mirzapur.

Bastar.—The whole State is capable of producing lac, but cultivation is only in the north. The rest of the State is so far from the nearest market (Dhamtari) as to make cultivation unprofitable except when prices rule high.

Should a railway ever pass through the State a definite impetus will immediately be given to lac cultivation, and the possibilities of production of high grade lac are very great. Both Kusum and Palas are common trees everywhere, but the present cultivation is nearly all Kusum.

The principal markets are :—

<i>Market.</i>		<i>State.</i>
Sahdol	... ..	Changbhakar.
Pendra	... ..	Korea and Sirguja (south-west).
Daltonganj and Garhwa	... ..	Sirguja (north-east).
Lohardaga	... ..	} Jashpur.
Raj Gangpur	... ..
Raigarh	... ..	{ Udaipur, Sakti, Raigarh, Sarangarh and Sirguja.
Tilda	... ..
		Kawardha.
Dongargarh	... ..	} Chhuikhadan, Nandgaon and Khairagarh.
Rajnandgaon	... ..
Dhamtari	... ..	Kanker and Bastar.

No action is proposed by Government. Most of the States have their own trained Forest Staff and are aware of the importance of lac as a source of revenue ; they may generally be relied upon to take the necessary steps to stimulate the industry.

DRUG.

This district is small and not of very great importance. Lac, however, is found throughout the district except in the Drug Tahsil. The south-eastern part including the Balod Forest Range is chiefly Kusum, the remainder being mostly Palas.

The principal market is Balod which is included with Dhamtari in Raipur district. A certain quantity finds its way to Rajnandgaon (Feudatory State). The zamindar of Khujji has shown considerable interest in cultivation, which he has largely extended.

Government action is hardly necessary in this district. The Balod Range Forests are included in South Raipur Division (See Raipur notes) and arrangements can probably be made with Khujji to supply brood in that locality.

BHANDARA.

Bhandara is an important district producing a particularly large and high grade Katki crop. The principal and almost only tree is Palas, which is found very abundantly in flat country on both sides of the narrow gauge railway from Gondia to Chanda and from Gondia northwards. Most of this forest is malguzari and zamindari, and there are only small patches of Government Forest. The Forest

Department has been in the habit of leasing out the right to cultivate and collect lac, but on the expiry of the existing leases it is proposed to cultivate departmentally.

The only important market is Gondia, to which also lac comes from Balaghat, Mandla, Seoni, Chhindwara and Chanda districts. Balaghat sends about 5,000 maunds annually. The others much less. Good crops in Gondia are :—

					Maunds.
Baisakhi	...	...	...	...	... 40,000
Katki	...	...	...	...	... 50,000

Contracts are generally very petty and the contractors are usually of low caste and poor education, financed by dealers and brokers who naturally pocket most of the profits. Contracts are usually for five to ten years and are very simple agreements. The consequence is that during the recent boom, unsophisticated contractors were tricked out of their contracts. They are now becoming more alive to their interests and are registering their contracts and taking legal advice. Cultivation is primitive in the extreme and the outturn could be largely increased by the introduction of improved methods. There is a good field for Government influence in demonstration and the supply of healthy brood-lac. A large area containing Palas should be acquired near Sonder or Dewalgaon Railway stations, and put in charge of the Forest Department, who with a staff of two or three men could control an area of 100 to 200 acres. This area would be managed as a brood farm and demonstration area and should result in at least doubling the present yield from Gondia market.

Alongside the Public Works roads and on the Bengal-Nagpur Railway embankments are large numbers of Palas trees at present uncultivated but to which lac has frequently spread by the agency of wind. It is understood that no revenue is at present obtained from these and it is suggested that leases should be offered to the public and development encouraged.

There are two small factories in Gondia owned by Mahibir Prasad Sundar Lal and Mahibir Prasad Ajodhya. They make TN shellac only. There is room for many more factories, but owing to there being no Kusmi available, only low grade shellac can be manufactured.

The principal Arhatiyas or commission agents are :—

Jagannath Ghansilal

and

Ramgopal Suraf Baran.

As each new crop enters the market numerous agents and dealers come to Gondia from Mirzapur, Jhalda, Balarampur and even from Calcutta, to make their purchases ; some also are permanently resident there.

BALAGHAT.

Cultivation is chiefly on Palas. The principal area is in the south-east adjoining Bhandara district. There are patches of lac elsewhere, but not many, and there is very little grown in Government Forest. The system of leasing and local conditions are similar to those in Bhandara district. The Forest Department is arranging for experiments to be made in a small area of forest used by the Forest School for practice purposes. No other Government action is required.

Balaghat district produces annually about 5,000 maunds of lac which is mostly sold in Gondia market.

MANDLA.

Mandla is a wild and jungly district, practically undeveloped so far as lac is concerned. The whole district is heavily wooded and there are large areas of Government Forest. A small quantity of lac is grown and numbers of small contracts are given out by Malguzars and by the Forest Department. The Kusum tree is fairly common in some parts of the North Mandla Forest Division and there are large areas of Palas forest, mostly however in Malguzari lands. On the expiry of the existing leases, the Forest Department proposes to take up lac cultivation departmentally. There will be no necessity for any action beyond that to be taken by the Department, which will be able to supply brood-lac and demonstrate methods of propagation and cultivation to owners of private forest. The contractors employed at present take very little interest in actual cultivation and merely collect the lac from tenants who cultivate at will or collect lac where it grows wild.

The South Mandla Forest Division is mostly Sal and is of doubtful value as a lac-producing area. It would be advisable to make a rough survey to discover whether Kusum occurs in any abundance.

JUBBULPORE.

Jubbulpore district itself does not produce a large quantity of lac, but is of importance in that it contains one large (Katni) and several smaller markets, within its boundaries. The only areas growing lac are a few blocks of forest, Government and private, in the extreme north, and extreme south (Bargi) and along the Damoh border and the Mahanadi river. The principal species is the Ghont everywhere except along the Mahanadi where Palas replaces it. A number of Palas trees also grow along the Jubbulpore-Seoni road between Gawalighat and Hulki. The Public Works Department leases out the right to cultivate lac on these trees.

There is room for considerable extension of the industry in Jubbulpore district. Ghont, Ber and Palas are common and the example of the P. W. D. might be followed with advantage by the railway, whose embankments are frequently covered with a strong growth of Palas.

Besides the principal market at Katni, there are smaller markets at Sihora and Jubbulpore. A good season should yield the following crops, but it is to be understood that with extensions of cultivation the yield could be much increased :—

	Baisakhi.	Katki.	Kusmi.	Jethwi.
Katni	25,000	10,000	600	300
Sihora	5,000	2,000	...	...
Jubbulpore	6,000	4,000	600	300

Not more than 10,000 maunds annually of this yield comes from Jubbulpore district. Large quantities come from the Malguzar forests of Damoh, Saugor and Mandla, and there is reason to believe that much lac is illegally removed across the borders from Rewah and other Central India States and from Damoh Government Forests. Katni also acts as a major market for much of the produce in the western districts of the Central Provinces, which each produce a small quantity of lac, namely Seoni, Chhindwara, Narsinghpur, Hoshangabad, Betul and Nimar. The system of collection is generally by lease to contractors. Madan Mohan Chaube of Katni. Marwara, a Malguzar, grows lac in his own forests and also takes

contracts. Most of the lac is brought in by Baiparis who buy from the small cultivators and lac thieves. Many contracts are made in villages along the borders merely to cloak thefts from Damoh, Rewah and other border States.

Lac, in Katni, is sold through Arhatiyas by the cloth method on *chaori* content. The Arhatiya, who takes Re. 1 per gon (3 maunds 30 seers) from the buyer and 6 or 8 annas per cent. from the seller, is generally a substantial merchant and often finances the wandering Baiparis. He also very occasionally advances money to cultivators on the understanding that the latter sell their lac to or through himself. There are no large buyers permanently settled in Katni. Agents from Mirzapur, which takes the greater part of the yield, come to Katni for each crop.

There is no manufacture of shellac at Katni. Madan Mohan Chaube owns a factory which used to turn out 10 to 15 maunds of shellac daily, but it has been closed for many years. Katni is quite a suitable site for a factory. The water-supply would not be difficult and the climate is favourable. The stick-lac supply is ample in the neighbourhood, both from private lands and Government Forests. Ghont, the principal local tree, yields high class Baisakhi and Katki lacs. Kusum lac can also be obtained from the Raipur side, which is in direct communication by means of the Bengal-Nagpur Railway.

Supplies of brood-lac could be arranged by the Forest Department, which intends to cultivate departmentally in the Government Forest of this district as soon as staff is available. No other Government action is necessary.

DAMOH.

Damoh is of interest as the centre of the Ghont lac area, and also as being the only district in which the Forest Department has seriously attempted lac cultivation.

The forest is roughly divided equally between Government and private proprietors and both have met with considerable success in lac cultivation. The Government Forests lie in the extreme north and in the southern half of the district. Around Damoh town the country is more open and contains less forest.

All the lac grown in Malguzari forests is sold in Katni bazar. The Forest Department disposes of its lac by auction or negotiation.

The annual yield from private forests is about 3,000 maunds, chiefly Katki. The yield of Katki from Government Forest in 1919-20 was 4,500 maunds, the largest yet known. As the work has only been taken up seriously during the last two years it is very difficult to make an estimate of its possibilities, but if conditions remain favourable it is likely that an annual crop of 10,000 maunds will eventually be reached. The principal difficulties to contend with are :—

- (a) the supply of labour for propagation and collection
- (b) the prevention of theft.

The recent boom in the price of lac has encouraged the organization of gangs of lac thieves in Damoh district, whose methods are said to be very efficient. The profits of their trade are so great that they are able to spend money lavishly in preparing for their exploits. One gang is credited with retaining a pleader to defend them against criminal charges. Experience has shown that the best way to defeat them is by a well-manned and well-paid protective staff, which will work in conjunction with the police. The Local Government has recently issued rules under section 41 of the Forest Act which will help in the detection of stolen lac in transit.

The private forests are worked either by contractors or by the owners themselves—usually men of substance who are sufficiently alive to their own interests to make proper provision for the supply of brood-lac. The Government Forests are ample and very suitable for the demonstration of improved methods. In 1919, owners of lac forests and others interested were invited to a demonstration of the methods employed by Government.

The principal growers of lac are :—

- Goulal Chanda, Malguzar of Mariadoh
- Pasan Kawat, Malguzar of Tendukhera
- Nur Khan, Contractor of Damoh
- The Raja of Hatri near Damoh.

SAUGOR.

The principal lac area in Saugor district is in the south and east along the Damoh border. The north-west (Khurai Tahsil) is more open country and contains much less tree growth. Ghont is the principal tree. There are extensive Government Forests in the south and east and they include a large part of the lac area. During recent years the Forest Department has undertaken the cultivation

of lac. The work has not been so successful as in Damoh, possibly as the Ghont tree is nearing its apparent limit. The chief reason for the poor returns obtained seems to be the depredation of thieves, and the prevention of theft is one of the principal aims of the Department. Most of the remarks under Damoh district also apply to Saugor.

The Malguzari forests produce about 1,000 maunds of lac annually which is sold in Katni; and no action of Government is required to stimulate the industry in these forests.

NARSINGHPUR.

This is not an important lac district, but is interesting in that it contains three distinct areas where three different kinds of lac are grown. Palas occurs in the east of the district. In the north is a small area which is a continuation of the Saugor-Damoh plateau and in which Ghont is the host-tree. In the south-west, round Mohpani, Kusum lac is produced, this tract forming part of the small Kusum area in Hoshangabad and Chhindwara districts which feeds the Bankheri market. Bankheri is a small market just within the Hoshangabad district in which chiefly Kusum lac is sold. Good crops are :—

						Maunds.
Kusmi	...	...	...	...	...	3,000
Jethwi	...	...	...	...	...	2,000
Baisakhi	...	...	...	...	...	2,000
Katki	...	...	...	...	...	1,000

A small quantity of lac is also sold at Narsinghpur. The principal suppliers at Bankheri are Girdhari Lal of Dongarhai, Hoshangabad district, and Onkar Prasad and Dhan Singh of Bankheri. The principal buyers are from Mirzapur. Lac comes chiefly from extensive private forests in all three districts, and also a small quantity from the Khairi Forest Range. Lac from the rest of the district goes to Narsinghpur and Jubbulpore.

The possibilities of this district are not great, but lac should be cultivated systematically in the three small patches of Government Forest which can then supply the brood-lac requirements of the district.

DISTRICTS OF MINOR IMPORTANCE IN THE CENTRAL PROVINCES.

*Nagpur, Wardha, Seoni, Chhindwara, Hoshangabad, Nimar,
Betul and the Berar Districts.*

Lac grows sporadically in most of these districts. Either ignorance or adverse climatic conditions or a combination of both are probably responsible for the fact that more is not grown. Spasmodic attempts have been made by the Forest Department to extend cultivation, but all have failed. A determined effort was made in central and western Hoshangabad in 1910-13 by an officer well acquainted with the cultivation of lac, but he met with little success. Of the Berar districts only the Melghat Forest Division in the Amraoti district produces much lac, and here there is most likelihood of extension by departmental cultivation. Attempts will probably again be made by the Forest Department when more staff is available, but at present their efforts should be concentrated in districts which offer more hope of success.

REWAH STATE.

Lac is found over the whole of the southern half of this State but about 80 per cent. of the outturn is from the two tahsils which lie along the Bengal-Nagpur branch railway from Katni to Bilaspur, the Chandia and Sohapur Tahsils. The yield has varied during past years from 53,000 maunds in 1913-14 to 12,000 maunds in 1917-18. Of this yield an average of 5 to 6 per cent. is grown on the Kusum tree, the balance being almost entirely Palas; and the Baisakhi crop is somewhat larger than the Katki.

The centre of the industry is at Umaria Railway station on the Bengal-Nagpur branch line, which passes through the middle of this lac area. The industry is thus very well placed in regard to rail transport, and in fact all conditions in the State are favourable to its propagation. The climate is suitable and the Palas and the Kusum are both royal trees; which means that, wherever they stand, those trees are the property of the State. As a corollary, all lac is the property of the State and control should, therefore, be very easy. The lac industry is in charge of the State Forest Department and the principal difficulties the Durbar has to contend with are the provision of an efficient and trained staff and the prevention of theft.

Without exaggeration there must be millions of Palas trees scattered over the two southern tahsils, and it is unquestionable that the production of lac might be increased almost indefinitely if sufficient staff and labour could be provided. Labour is none too plentiful but with such labour as is available the annual outturn in a good year might be raised to 100,000 maunds if control were efficient. Effective control must include the prevention of smuggling across the boundary, for lac theft is rife in this part of India and probably causes a very heavy annual loss to the State. It is difficult to suggest a remedy, but the State is no doubt making every possible effort to prevent illicit removals.

The system employed by the Forest Department is direct departmental cultivation. The ultimate unit is a *lakhera* (lac plot) in charge of a *lactora* (lac cultivator). Theoretically the system of cultivation adopted is scientific, but owing to a shortage of trained staff the practical result is the survival of primitive methods. The *lactora* is responsible for the propagation, protection and collection of lac within his area and receives as his pay 2 annas per seer of lac produced.

The State has a very well built and equipped shellac factory at Umaria, capable of dealing with all the lac produced within its jurisdiction. The methods employed are similar to those in Mirzapur and Balarampur. The quality of shellac produced approximates to TN standard. The manufactured article is disposed of in Calcutta.

UNITED PROVINCES.

The United Provinces are comparatively unimportant as lac growing areas. It seems likely that in early days the province produced much larger quantities than at present, but field cultivation has become so intense that little culturable land remains uncleared and the demand for fuel has become so great that what little waste land there is has been more or less cleared of trees. The possibilities of the extension of lac cultivation are therefore not great, and what cultivation exists is so scattered that there is little hope of development except in the south of Mirzapur district, which is dealt with separately. Apart from Mirzapur the more important areas are Bahraich, Gonda, Kheri, Shahjahanpur, Lucknow, Cawnpore, Saharanpur, Aligarh, Bareilly, Meerut and Moradabad.

The principal trees in the U. P. on which lac grows are Palas, Pipal, Banyan and Ber. A small quantity is said to be grown on the

Kusum tree in Kheri district. The methods of cultivation are primitive. The system is usually one by which contractors do the work of propagation, cultivation and collection by daily labour.

The principal markets and good crops are :—

					Baisakhi.	Katki.
Mathera (Bahraich)	...	...	...	...	2,000	3,000
Rissia (Do.)	...	...	...	...
Hatras (Aligarh)	...	...	...	...	1,000	1,000
Lucknow	...	...	...	...	1,000	1,000
Singai (Kheri)	...	...	...	...	2,000	2,000
Cawnpore	...	...	...	...	1,000	1,000
Saharanpur	...	...	...	...	3,000	2,000
Bareilly	...	...	...	...	3,000	1,000

The figures given above are admittedly approximations only.

The principal dealers are :—

Mathera.—Mangal Ram Narayan.

Rissia.—Kalicharan.

Lucknow.—Haji Elahi Bakhsh Sharif Uddin.

Cawnpore.—Moolchand Bania (Bhoosa Toli). Lachman Dass Jagannath (Nanghara).

Bareilly.—Sibba Manhar (Mohalla Nala). Nanha Manhar (Mohalla Akub Kotwali).

There is one shellac factory at Cawnpore belonging to Salikram Kalloomal of Baconganj, who manufactures TN chiefly. He takes large quantities and the balance goes to Mirzapur whence buyers come at the crop periods.

Attempts have been repeatedly made by the Forest Department in various districts to extend the cultivation of lac, particularly on Palas, but they have not met with any success.

Cultivation can never be very extensive or very important in the U. P. and for this reason Government action is hardly called for, except for any experiment which the Forest Department may care to undertake. If such experiments prove successful the question can be reopened.

MIRZAPUR.

Mirzapur is chiefly of importance as the largest lac-manufacturing centre in India. The bulk of the district produces no lac, but the area south of the Sone river produces considerable quantities. This area naturally forms part of the Palamau district of Bihar and Orissa. In racial and other characteristics both areas are similar, and Mirzapur stick-lac finds its way mostly to Garhwa Road station on the Daltonganj branch railway, Palamau. In fact it is impossible to distinguish Mirzapur lac from that of Palamau. Only a small quantity of the former finds its way to Ahraura station on the East Indian Railway main line.

The system of cultivation in Mirzapur is the usual very primitive method. The principal tree is Palas with a little Ber and some other trees. The cultivation is generally by individual tenants and not by contractors, each tenant cultivating his own few trees in his own interest. A large part of Mirzapur district south of the Sone river is Government Estate and the forest is largely Government Protected Forest managed by the Revenue staff. Here only lies any possibility of improvement of cultivation by Government action, but it is very difficult to suggest means. It is an isolated area with a small forest staff. It is hardly worth while taking any special action such as the formation of brood farms or the appointment of a special scientific staff and the area will have to depend for brood and demonstration on such action as may be taken by the local authorities in Palamau.

The chapters relating to manufacture and to the internal trade of India describe the ordinary lines of business as conducted at Mirzapur. A feature of the trade is the Chapra Vyapar Bardhini Sabha, or "Association for the Improvement of the Shellac Trade," which has existed for some years past at Mirzapur. The membership roll includes the names of some eighty-four firms in all, representative of dealers and brokers, as well as of the fifty odd local manufacturers. The principal object of the Association is the decision of disputes between members. The executive committee passes orders on such disputes, but also refers to a meeting of the general committee any point of special importance requiring their decision; naturally, however, such references are not numerous. It is also the business of the executive committee to draw samples every six months, and to give their official sanction to these as standard samples of the incoming crop.

The following is a list of the principal manufacturers of shellac in Mirzapur :—

Kilburn & Company
C. J. Lucas
John Edmond & Co.
Mahadeo Prasad Kashi Prasad
Gopaldas Kandhaiyalal
Dhansukhdas Jethmal
Hiralal Jhabbulal
Garibram Chhedilal
Baldeodas Sarju Prasad
Madan Chand Gangadhar
Kandhaiyalal Onkarnath
Ghasiram Baldeodas
Baijnath Bhagwandas
Balkrishna Jagannath
Mannalal Bhagwandas
Balairam Jokhairam
Aladad Imamuddin
Ghosh Mohammad Khairuddin
Bindraban Mahadeo
Radha Raman Agarwala
Bhuddulal Rang Lal
Shaik Abdul Karim
Ganesh Prasad Narayan Das
Haridas Balramdas.

The following are the principal Arhatiyas and dealers in stick-lac :—

Jamunadas Panna Lal
Lachhman Das Manrakhan Lal
Ghasiram Baldeo Das
Lachhmi Narayan Hanuman Das
Jitmal Girdhari Lal
Anant Ram Sajan Kumar
Hiralal Jhabbulal.
Seth Sewaram Khushhal Chand
Ram Lal Makund Lal
Gobind Ram Sita Ram.

Brokers :—

Hardas Agarwala
Badri Prasad Tiwari
Gaya Prasad Agarwala
Maheshilal Agarwala
Ganpatlal Marwari
Lachhmi Narayan
Manni Ram Pande
Gopaldas Agarwala
Kandhaiyalal Marwari
Shambhulal Khatri
Haridas Khatri
Madan Lal Khatri
Bulakiram Agarwala
Ajodhia Prasad Bania
Chhedilal Khatri
Ram Sunder Pande
Munni Lal Chaube.

Shellac Exporters (Commission Agents):—

Dhansukhdas Jethmal
Gopal Das Kandhaiya Lal
Kishun Prasad Bisun Prasad
Mohan Lal Onkarmul
Ganesh Das Hardat Rai.

PUNJAB.

With the exception of one district, this province is of no importance as a lac producer. Small quantities are produced in Amritsar, Delhi, Guzerat and Karnal and perhaps other districts ; but the province as a whole has climatic conditions too extreme for the successful propagation of lac. The exception, Hoshiarpur district, is a distinct anomaly and produces quantities of lac of some importance to the trade. The lac-bearing areas are principally in the Una Tahsil with smaller areas in Dasuya and Garh Shankar but very little in Hoshiarpur Tahsil. A small quantity also comes to Hoshiarpur market from Nadaun in Kangra district. The apparent cause of this anomalous growth of lac is the existence of the Siwalik Hills between which and the Himalayas lies the lac-bearing area, a long narrow valley along which flow tributaries of the Sutlej and Beas rivers. The Siwalik

Hills run from north-west to south-east and the valley is shut in to the south-east by the Simla Hills and to the north-west by the Kashmir Hills, and is therefore protected on all four sides. One would naturally expect to find special climatic conditions ruling in such a locality. The rainfall in Una Tahsil is certainly greater than at Hoshiarpur outside the valley, which must in general enjoy a somewhat more favourable climate than is to be found in the more exposed portions of the district. It is at present only surmise that the Una Tahsil owes its lac to these peculiar conditions, but this seems to be the natural conclusion.

The principal lac-growing species is Ber which exists, or has been sown specially for the purpose, round the village sites. Small quantities are also grown on Babul and Ficus spp. The cultivation is much the same as elsewhere, a few trees being always reserved for brood. There appears to be no difficulty about brood-lac and the industry seems to be thriving. The actual work is done by the land-owners. They sell their lac to Baiparis who bring it to Hoshiarpur for sale, chiefly to agents of Mirzapur and Imamganj firms who come to make their purchases each season.

Good crops are :—

					Maunds.
Baisakhi	...	...	...	...	15,000
Katki	...	...	...	...	10,000

The basis of sale is the local lac maund of 54 seers 2 chattaks. The odd two chattaks are the perquisite of the buyer's agent. The Arhatiya recovers two pice per rupee from the seller and 1 per cent. from the buyer.

The principal Arhatiyas are :—

- L. Thakur Dass
- L. Mukunda Mall
- L. Gujar Mal Mikki Ram
- Birja Mal Teghu Mal
- Gurdita Mal Md. Baksh
- Rup Ram Balik Ram
- Sri Kishan Dass Bansi Lal.

The only known contractor is Ghulami Kasi, District Board Contractor.

There is no manufacture of shellac in Hoshiarpur. Local wood and metal workers import an insignificant quantity from Mirzapur.

The existing Kangra Forest Division includes the small areas of Government Forest in Hoshiarpur district. It is proposed to divide the whole division into two, and a Forest Officer may then be posted to Hoshiarpur. In this case the Forest Department will be able to study the question of lac cultivation in more detail than has been possible till now. If sufficient trees occur in Government Forest, the demonstration of scientific cultivation and the provision of clean brood-lac to private cultivators at reasonable prices will undoubtedly stimulate the industry and prove of considerable profit to the Department.

BOMBAY-PRESIDENCY.

In Bombay Presidency proper, lac is at present of very little importance. Small quantities are grown in Khandesh, the Dangs and the Panch Mahals, and in adjoining territories of Baroda and other States, but the total amount grown is unimportant.

Sind, however, produces lac on a scale of considerable importance to the trade. It is mostly grown in the two districts, Hyderabad and Karachi, on both sides of the lower Indus. Sind is usually considered one of the hottest and driest parts of India. This being so, the occurrence of lac there must be regarded as somewhat of an anomaly. A suggested explanation is that on the lower Indus sea-breezes during the hot weather do much to reduce the severity of the climate. No definite reason can however be assigned without careful local investigation.

Another curious fact about Sind lac is that it is mostly grown on the Babul tree, which, except sporadically in the Punjab, is found nowhere else in India as an important lac-host. Possible explanations of this have been discussed in Chapter II. Lac is also grown on *Prosopis spicigera*, *Zizyphus Jujuba*, *Albizzia Lebbeck*, *Tamarix gallica* and *Ficus* species, but these are all of comparative unimportance compared with Babul. The methods of propagation, cultivation and collection are much as in other parts of India, but the times of swarming are somewhat later.

The principal contractors and dealers are :—

Akhund Hassanali of Matiari, Hyderabad

Rewachand Permanand of Hyderabad

Gobinbax Hassomal of Hyderabad

Sajan Mohamed Hashim of Matiari

Chatomal Metholal of Hyderabad

Deomal Sadarangani of Hyderabad.

Most of the lac is grown on private lands.

The average outturn from the Government Forests of Hyderabad and Jerruck Divisions is about 1,000 maunds, while the Public Works Department obtains almost as much from lands in its charge. Contracts are usually given and there is little departmental cultivation. The total outturn of Sind is supposed to be about 20,000 maunds Baisakhi and 6,000 maunds Katki annually, but these figures are not very reliable. The greater part of this lac is exported to Mirzapur for shellac manufacture, but before the war an average of 5,500 maunds of grain-lac was manufactured at Hyderabad and exported from Karachi, the principal exporters being Messrs. Donald Graham and Co., and Messrs. Ralli Bros.

The quality of Sind lac is hardly equal to the Indian Baisakhi and Katki, but is better than either Assam or Burma lac and is suitable for TN manufacture.

Government Forests have been in the habit of supplying brood-lac when required. It is suggested that they might now go further and experiment with departmental cultivation.

BENGAL.

The only important areas in the Bengal Presidency, as now constituted, are the extensions of the Sonthal Parganas (Pakaur) area into Malda, Murshidabad and Birbhum districts, and of the Manbhum area into Bankura and Midnapur.

The Malda lac area is a fringe along the Ganges. In Murshidabad, the Jangipur sub-division produces a large quantity of lac and it occurs scattered in other parts of the district. In Birbhum, the northern part of the district produces most lac. Pakaur forms the centre of the lac industry for all these areas, with subsidiary markets at Dhulian, Jangipur, etc.

A fair quantity of lac is grown in the west of Bankura and Midnapur adjoining Manbhum and it grows sporadically in many other parts of these districts. Apparently the cultivation of lac was once on a much larger scale, as the Bengal administration report of 1901-02 states that "the manufacture of shellac is an important industry in the Bankura district and is chiefly carried on in the town of Sonamukhi"—"the main supply of this article for all the factories

in Bankura is obtained from the districts of the Chota Nagpur Division." During the last decade this industry has almost disappeared. The reasons are probably that the factories at Sonamukhi could not compete with the Chota Nagpur factories, that the cultivation being near its limit was precarious, and that Palas trees were cut down as field cultivation intensified. The district officials are, however, hopeful that the industry will revive.

The principal host-tree is Ber, almost exclusively in Murshidabad but mixed with Palas and other species in other districts, and with a little Kusum in Bankura. The methods of cultivation are as in the Sonthal Parganas and Manbhum, but in Murshidabad and Makda the cultivators are of a higher class and are more careful to maintain the brood which they also supply in large quantities to the Sonthal Parganas. It is probable that the methods of cultivation in the Jangaipur sub-division are as good as anywhere else and a proper rotation of trees is really attempted. Cultivation is also very intense, particularly in Murshidabad, and these Bengal districts supply the greater part of the lac in Pakaur market. The following cultivators in Murshidabad district are said to produce over 100 maunds each annually :—

Mohammad Bogdad Biswas, Shahebnagore

Hazi Basti Mandal, Debidaspur

Rahahak Biswas, Ghaneshyampur

Hedatulla Biswas, Shutitala

Ahasadtulla Biswas, Babupur

Jafar Munsî, Haripur

Bholai Biswas, Jote Kashi

Jagir Munshi, Shikdarpur

Madhusudan Shaha, Kohatpur

Rajendra Nath Shaha, Kohatpur

Adhar Shaha, Kakwira

Hazi Jatra Monim, Chachanda

Golap Monim, Chachanda

Umesh Mandal, Basudebpur

Isan Mandal, Jaladipur

Kifatulla Mandal, Loharpur

Moharkhan, Harinandanpur

Bhaglu Mandal, Harinandanpur

Jadunath Das, Faridpur.

Ashutosh Tewari, Sherpur.

No Government action is proposed in this area as cultivation appears to be based on sounder principles than elsewhere. The Pakaur area will benefit from any action taken in the Sonthal Parganas and the Bankura area from any in Manbhum.

Calcutta is an important manufacturing centre, the largest machine manufacturers having their factories there. They are :—

Messrs. Angelo Bros., Cossipore

J. C. Galstaun, Esq., Calcutta.

A considerable stick-lac market exists in Calcutta for the supply of these factories. The bulk of this lac has, however, already passed through one or other of the up-country markets, except the Assam and Burma lac, of which these factories take almost the whole supply. Being the shellac market of India, Calcutta is very convenient as a site for lac factories, but on account of the high price of labour, distance from the stick-lac centres, and high humidity which necessitates special precaution against the blocking of stick-lac and shellac, it cannot be recommended.

ASSAM.

The position of lac in Assam is unique in that it is not, as elsewhere, a forest product, but is grown chiefly on a field plant, Arhar Dal. Assam has a large rainfall and considerable falls occur during the hot weather months, especially in the hills, so that Arhar, which is an annual elsewhere in India, persists for several years, and is able to bear a crop of lac. Certain forest trees also produce lac, notably *Ficus religiosa* (Pipal) and *Ficus infectoria* (Pakri), but the bulk of the Assam lac is grown on Arhar. The distribution is mainly in the hilly tracts, and it seems as if the plains are too humid for lac cultivation. It may be seen well distributed on the hills in the territories of the Raja of Rambrai (Khasi Hills). The following areas produce lac and the quantities given are normal average yields :—

					Maunds.
Khasi and Jaintia Hills	...	...	...	...	15,000
Garó Hills	...	...	...	...	9,000
Nowgong district	...	...	...	...	7,000
Kamrup	...	...	...	...	3,000
Sibsagar	...	...	...	...	1,000
Total	...	...	...	...	35,000

The winter and summer crops are known locally as **Katwan** and **Jethwi**, from the months in which the crops are generally collected. **Jethwi** is used principally as a brood crop and the amount which reaches the market is small (about 5,000 maunds on an average) compared with **Katwan** (about 30,000 maunds). An insignificant quantity of the lac is imported into Assam from Bhutan.

Most of the Assam lac is cultivated by aboriginal tribes on the hills by shifting cultivation, locally known as "jhuming." Jungle is cut down and burnt, and **Arhar Dal** is sown in the burnt soil. The plants are allowed to attain one year's growth and are then infected. After the collection of the lac, the plant sprouts again and a second lac crop can be reaped a year later. As the host only persists for a few years, regular infection is obligatory, and hence more thorough than in India. The practice of infecting by small quantities of brood-lac, which are left for a season or two to reproduce naturally and thus fully infect the host, is not possible. After the death of the host, "jhuming" is carried on to a fresh area, where cultivation is repeated; and the result tends to the destruction of the forest.

The cultivators take their lac in small quantities to the small bazaars at the foot of the hill and dispose of it to Garo and other traders, generally in exchange for opium and salt, cloth and (more rarely) cash. Opium is the commonest. Naturally the cultivator gets very much the worst of the bargain, and only when prices are very low does he get anything like his proper share of the proceeds. He is generally indebted to the trader who is thus able to pay his own price for the lac.

The traders send their lac to the big export markets, principally **Barapani** (Nowgong) and **Palasbari** (Kamrup) whence it is despatched by train or steamer to Calcutta. The principal subsidiary markets are—in the Nowgong area: **Kalanga**, **Lopani**, **Meragar**, **Katri**, **Jogi**, **Nilihat**, **Nekra**; in Sibsagar area: **Golahat**, **Dimapur**, **Bartalawa**, **Birkarkhat**; in the Garo Hills: **Tura**, **Dubri**, **Damra**; in the Kamrup area: **Bokhu**, **Singra**, **Goalpara**, **Jaintiapur**.

The largest dealers are:—

Joynarain Goadhan Agarwala, 94, Lower Chitpore Rd.,
Calcutta, whose local office is Joynarain Sonairam of
Gauhati

Nandram Bhairondan of Barapani, Nowgong

Lakmi Chand Gulab Chand of Lopani

Gewar Chand Dharam Chand of Lopani

Budaimal Pannalal of Barapani

Ansukra Bala Baksh of Kalanga near Barapani

Chot Mal Malab Chand of Lopani and Meragar Baghicha.

There is no manufacture in Assam. Years ago a planter, Mr. Beecher, started a factory at Gauhati which closed down on his decease. Assam lac is produced in fine large incrustations, but is not up to Indian lac either in colour or quality, although it is considerably superior to Burma lac. It is not usually used for TN manufacture except when demand is high and the Indian crop is poor. The Calcutta manufacturers take most of the crop and it is said to be particularly suitable for making garnet lac.

Prior to 1914, lac was classed as a forest product and the Forest Department realized an export duty of Rs. 2 per maund (calculated to represent $12\frac{1}{2}$ per cent. *ad valorem*). Mainly owing to protests from the trade the duty was removed in 1914, with the object thereby of stimulating cultivation. This effect has not, however, been secured to judge from the Assam export figures below.

So far as Government lands are concerned the right to collect lac revenue was leased out until 1907; and between 1907 and 1914 the revenue was collected departmentally. Neither method was, however, found satisfactory. A small quantity of lac is grown in lands under permanent settlement and in Government leased lands (*raiyatwari*) but it is insignificant. Government's share of lac revenue is included in the rents fixed at settlement and Government has therefore never claimed a separate lac revenue from these areas.

The Forest Department is thus no longer directly interested in the crop. It is suggested that either this Department or the local departments of Agriculture or Industries should take such measures as are possible to study cultivation and to stimulate the adoption of up-to-date methods. The practice of "jhuming," which is most frequently found to occur in unclassified forest and Feudatory States, might with advantage be discouraged in favour of cultivation on sounder and more permanent lines.

The statement below shows the exports of lac by rail and river from Assam from 1899-1900 to 1918-19. There are no exports from Assam across the frontier :—

Years.					Exports. Cwts.
1899-1900	...	...	...	...	11,276
1900-01	...	...	...	...	13,363
1901-02	...	...	...	...	22,597
1902-03	...	...	...	...	21,830
1903-04	...	...	...	...	24,121
1904-05	...	...	...	...	28,643
1905-06	...	...	...	...	26,753
* 1906-07	...	...	...	...	33,162
* 1907-08	...	...	...	...	32,700
* 1908-09	...	...	...	...	11,051
* 1909-10	...	...	...	...	35,386
* 1910-11	...	...	...	...	31,618
* 1911-12	...	...	...	...	30,762
1912-13	...	...	...	...	26,092
1913-14	...	...	...	...	19,787
1914-15	...	...	...	...	21,717
1915-16	...	...	...	...	37,467
1916-17	...	...	...	...	23,842
1917-18	...	...	...	...	15,692
1918-19	...	...	...	...	27,091

BURMA.

Burma lac has been for many years of some considerable importance to the trade. It contains a high proportion of colouring matter and was prized in early days by the manufacturers of lac-dye. Unfortunately, this detracts from its value as the raw material for the manufacture of shellac. Comparatively little has ever been exported to foreign countries direct, either in the crude or manufactured state, and it is now principally shipped to Calcutta on order from manufacturers using mechanical processes; but, when the Indian crop is short, TN manufacturers also buy Burma Lac, to blend with Baisakhi and Katki.

* These figures relate to the province of Eastern Bengal and Assam as it was constituted after the partition of Bengal.

The following table shows the shipments of Burma lac to Calcutta during each of the years 1866-67 to 1919-20:—

Year.	Cwts.	Year.	Cwts.
1866-67	1,483	1894-95	10,836
1867-68	545	1895-96	24,369
1868-69	1,593	1896-97	9,330
1869-70	460	1897-98	10,884
1870-71	588	1898-99	8,630
1871-72	<i>Nil</i>	1899-1900	9,290
1872-73	3,906	1900-01	11,027
1873-74	21,483	1901-02	15,108
1874-75	14,893	1902-03	21,668
1875-76	4,216	1903-04	30,797
1876-77	8,594	1904-05	24,703
1877-78	4,343	1905-06	26,715
1878-79	Not issued.	1906-07	27,214
1879-80	6,203	1907-08	14,259
1880-81	11,499	1908-09	21,292
1881-82	6,999	1909-10	15,081
1882-83	3,781	1910-11	27,284
1883-84	4,370	1911-12	1,777
1884-85	1,649	1912-13	9,454
1885-86	2,926	1913-14	6,359
1886-87	3,052	1914-15	2,964
1887-88	2,919	1915-16	19,346
1888-89	3,805	1916-17	24,347
1889-90	2,244	1917-18	15,817
1890-91	4,655	1918-19	18,559
1891-92	5,923	1919-20	45,036
1892-93	9,063		
1893-94	11,663		

There was a marked decrease in exports during the decade 1881—1890, when the lac-dye industry was expiring and shellac had not yet come to its own. It is also noticeable that when the Calcutta shellac market is depressed, the shipments from Burma to Calcutta almost disappear, but increase when the market revives. Thus in the four years 1904—07, when prices were high, the average annual exports to Calcutta exceeded 25,000 cwts. In 1913-14 and 1914-15, when Calcutta prices were low (Rs. 30—40 per maund), Burma shipments were only 6,359 cwts. and 2,964 cwts. During the three following years, when prices rose materially to Rs. 80—100, shipments were in the neighbourhood of 20,000 cwts. per annum.

Distribution follows two more or less definite zones, one lying along the eastern slopes of the Arakan Yoma and the other in the hilly country of the Northern and Southern Shan States. In the former it is known to occur in Henzada, Prome, Thayetmyo, Minbu, Pakokku, Chindwin, Katha and Bhamo districts, and probably occurs in others too. The Irrawady river forms the main line of export to Rangoon. Many of the Shan States produce lac, Hsipaw and Maymyo being the centres in the Northern, and Taungyi in the Southern Shan States. These States have very poor communications and the actual distribution is unknown, but is undoubtedly widely spread, for lac even enters them from China, Thibet and Siam.

There is very little lac cultivation in Burma, most of it growing wild. In Henzada district it grows only on the tops of the hills above 2,200 feet in most inaccessible places and very scattered. The principal host-trees are *Pentacme suavis* (Thitya), *Shorea obtusa* (Ingyin), *Dalbergia cultrata* (Yindaik), *Aporosa Roxburghii* (Yemein), *Dipterocarpus tuberculatus* (In), *Croton oblongifolius* (Thetyingyi) and *Ficus spp.* In this tract the crop usually has an injurious effect on the trees, for it is only collected spasmodically and brood after brood emerge and cover every available part of the tree with lac, which exhausts its energies and results in its death. Further north and in the Shan States, lac grows also on *Butea frondosa* (Pauk) and *Zizyphus Jujuba* (Zi) and is found there at lower altitudes than in Henzada.

Some confusion has occasionally arisen between lac and Burmese lacquer. The latter is a gum obtained by tapping *Melanorrhæa*

usitata, locally known as Thetsi, and is quite different from lac. Stick-lac is known as *chaik* and *biuli* lac as *chaiktha*. The trade is mostly in the hands of Chinamen, who in the usual course take contracts from the Forest Department and send their agents to the forests to collect from the local Burmese. One Chinaman is said to be growing lac on Arhar *Cajanus indicus* (pe-singon).

Most of the lac is brought in by Chinese merchants carrying on their business in Tsee Kai Maung Taulay Street, Rangoon. Messrs. Martin and Co., Ltd., 10 Strand Road, are also interested in the industry. Two firms, The Eastern Lac Refinery Co., Ltd., and the Burma Lac Refinery Co., Ltd., commenced manufacture in Rangoon, but both were wound up before the war. Mr. Apar of Maymyo makes grain-lac on a small scale. Unless a better quality stick-lac can be produced it is very doubtful whether shellac factories will be financially successful except at periods when trade booms.

The principal exporters of stick-lac in Rangoon are:—

H. Palladroy, 51, Merchant Street

Naitram Rambar, 2 Mogul Street

M. T. Lutman Narayan, 3 Merchant Street

N. Jugganath, 1 Mogul Street

B. Rung Lall, 46 Strand Road.

As already stated, Burma lac contains a large quantity of lac-dye; and the resin itself, besides being more highly coloured, is of much poorer general quality than the Indian product. These defects seem to be inherent and due to climate or locality and it is very doubtful if Burma can ever produce higher grade lac. It follows that the demand for it is never likely to be constant as all manufacturers, including those who have adopted mechanical processes, prefer Indian lac if they can get it. As there is great hope of increasing the Indian supply considerably, attempts to extend the industry in Burma are not likely to be successful.

Only a small revenue is obtained by the Forest Department from contracts for lac collection, in addition to the export duty of Re. 1 per maund which is collected by the Custom-house at Rangoon and credited to the Department.

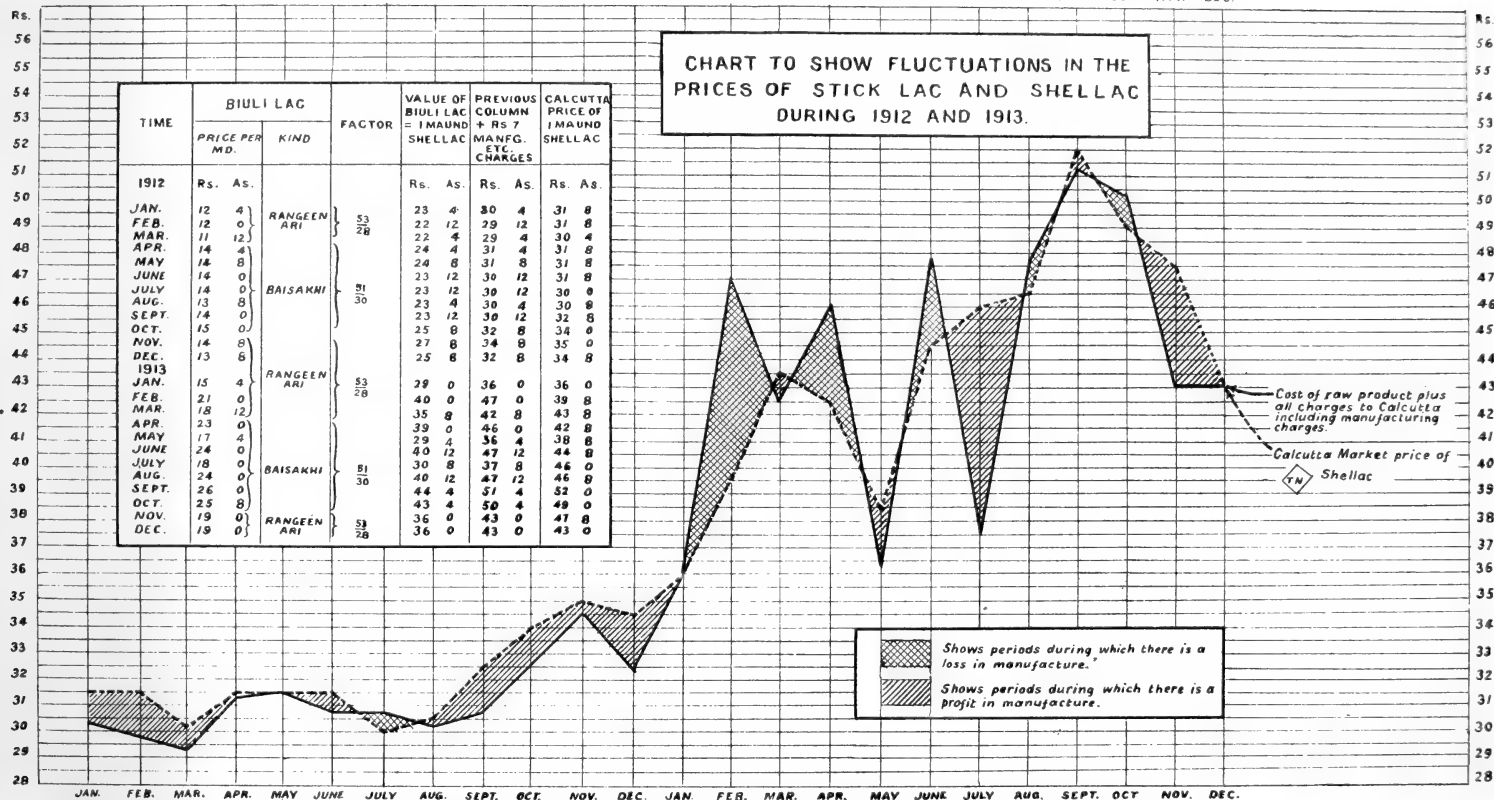
An interesting fact is that Kusum, locally known as Gyo, is quite common in Burma, and is almost regarded as a weed in the forests. No lac was found growing on this tree, which produces

in India a quality of lac superior to any other. It is strongly recommended that the newly constituted research branch of the Forest Department should undertake lac cultivation on an experimental scale especially on Gyo and Zi. If the former is found to produce a lac of anything like the quality it produces in India there is bound to be a heavy demand for it. Brood for the Zi tree can be obtained locally but for the Gyo tree must be obtained from the Forest Department of the Central Provinces.

1912

JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. 1913

1913



1912

1913

II

**CHART TO SHOW EFFECT IN INVERSE OF LONDON STOCKS ON
CALCUTTA PRICES, JANUARY 1901 TO JANUARY 1919.**

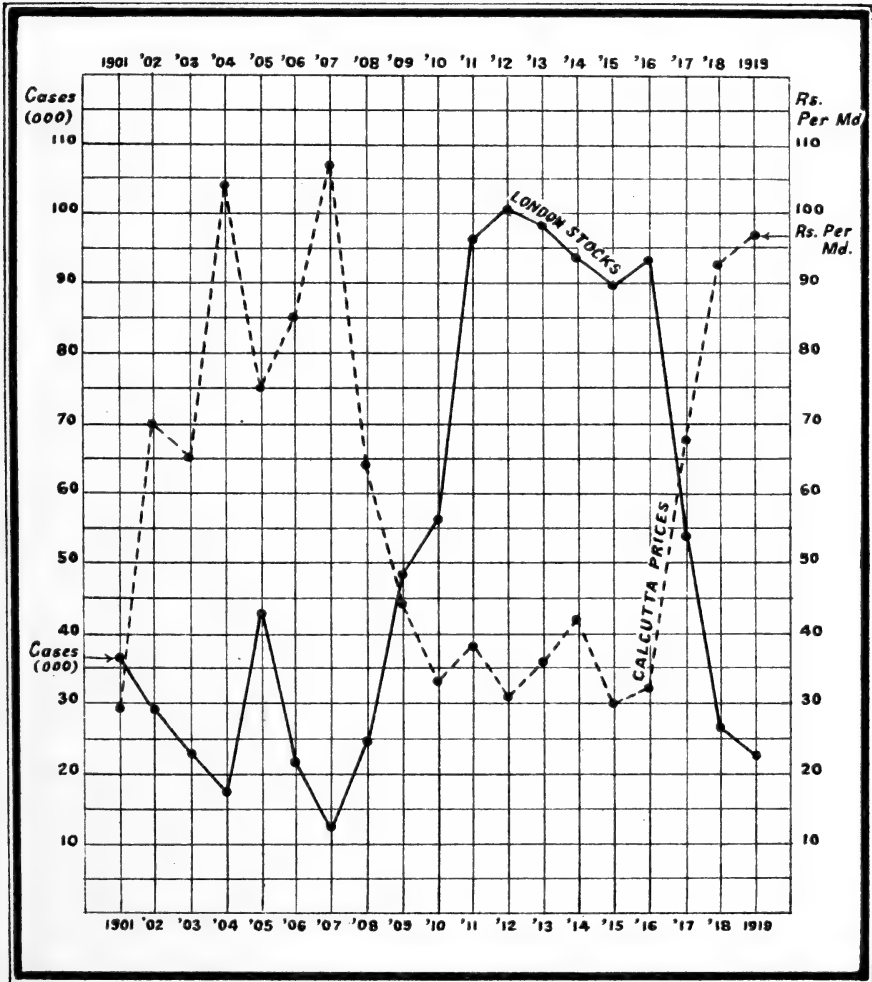
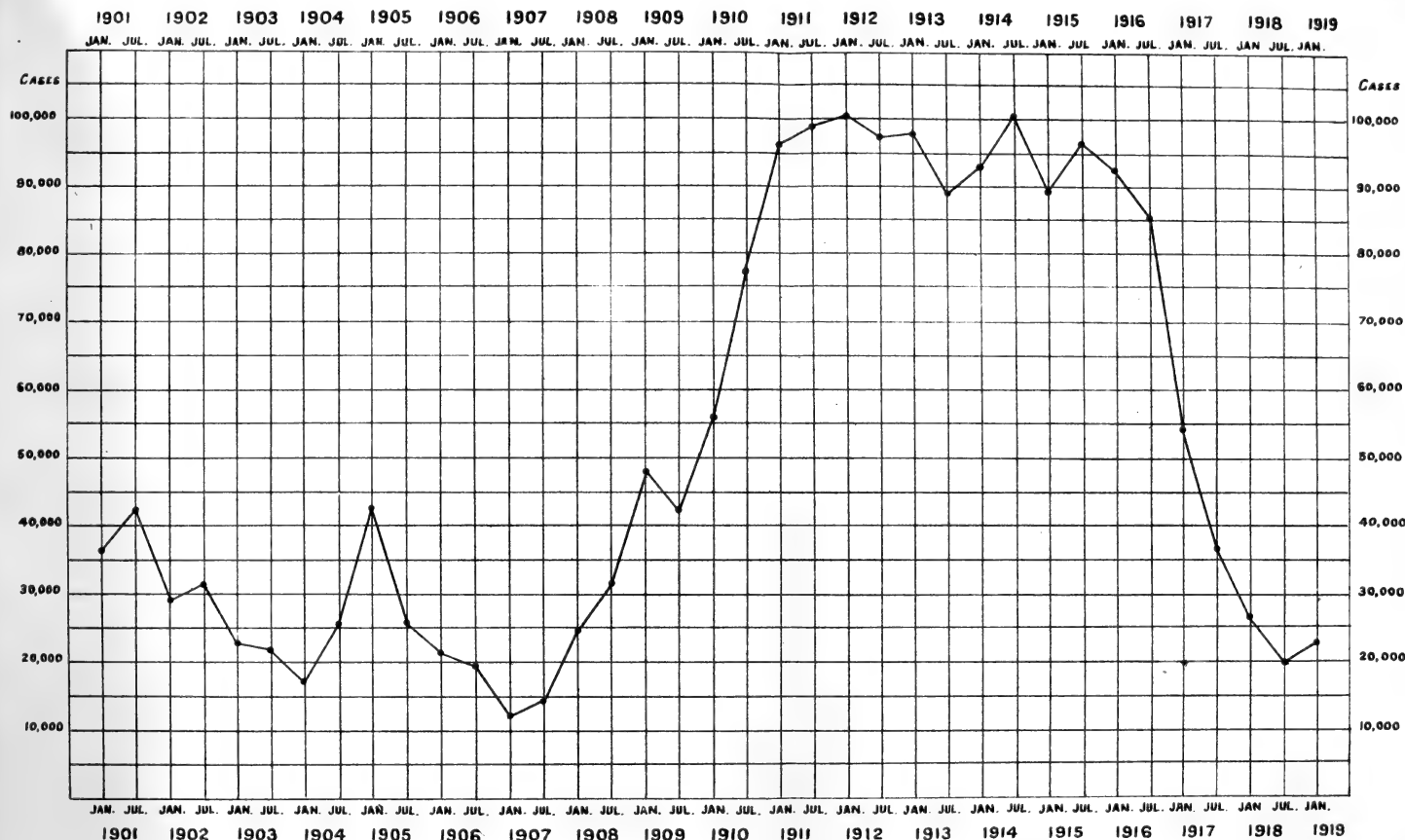


Photo. Zinco., August 1920.—No. 1178-1.3000.



III

CHART TO SHOW SIX-MONTHLY FLUCTUATIONS IN LONDON STOCKS OF SHELLAC JANUARY 1901 TO JANUARY 1919.



IV

CHART TO SHOW SIX-MONTHLY FLUCTUATIONS IN LONDON PRICES OF  SHELLAC JANUARY 1901 TO JANUARY 1919.

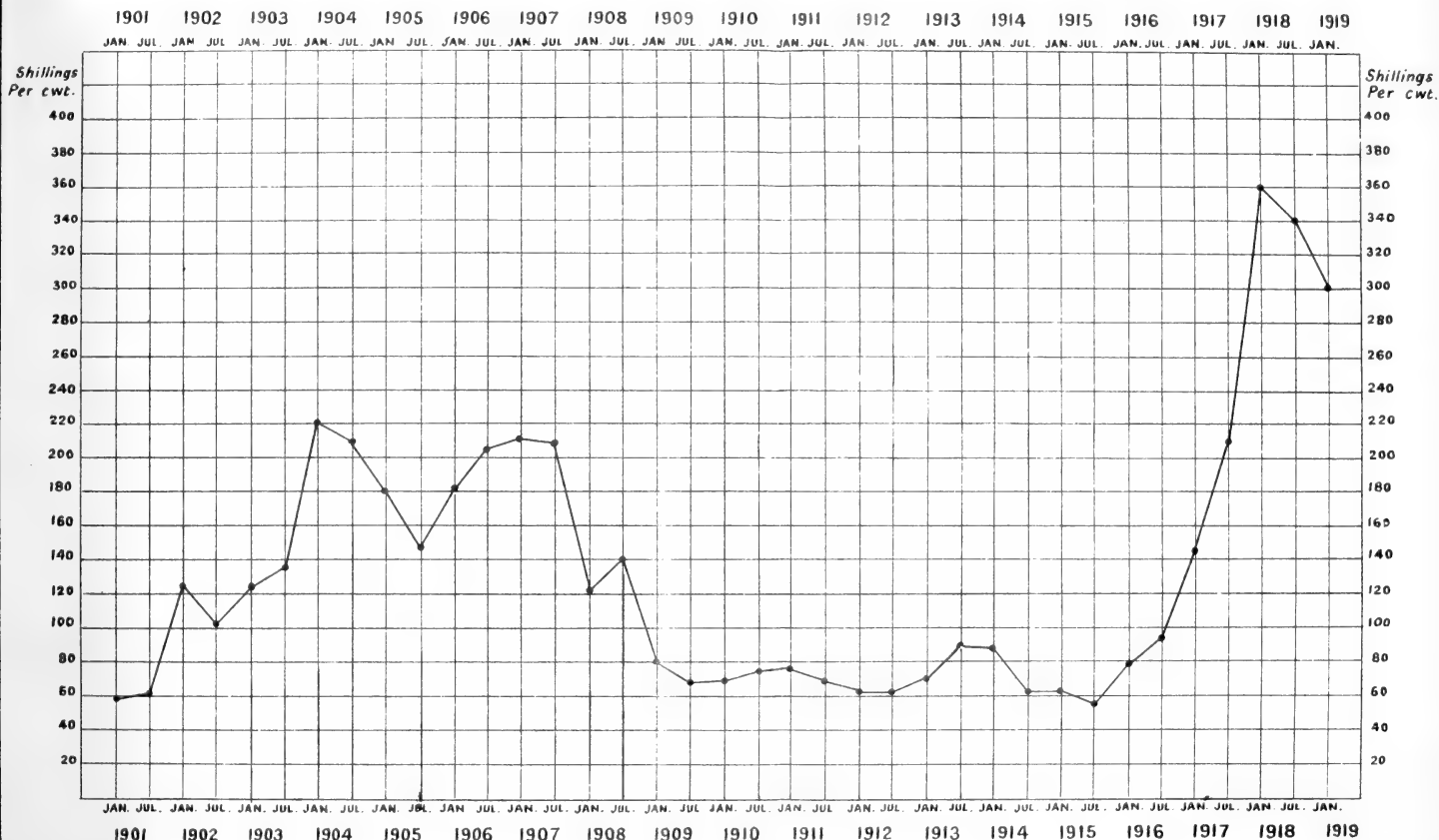
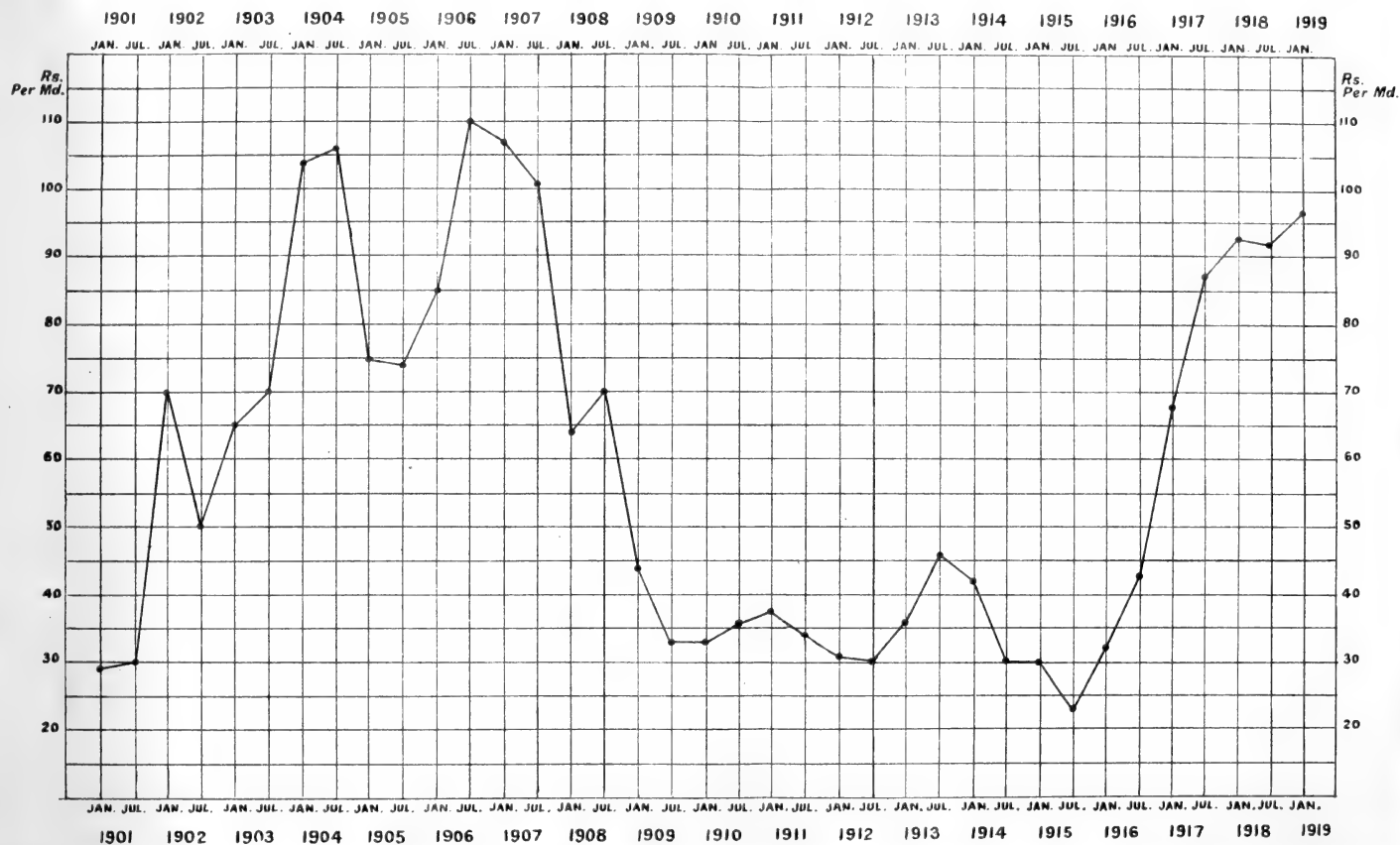
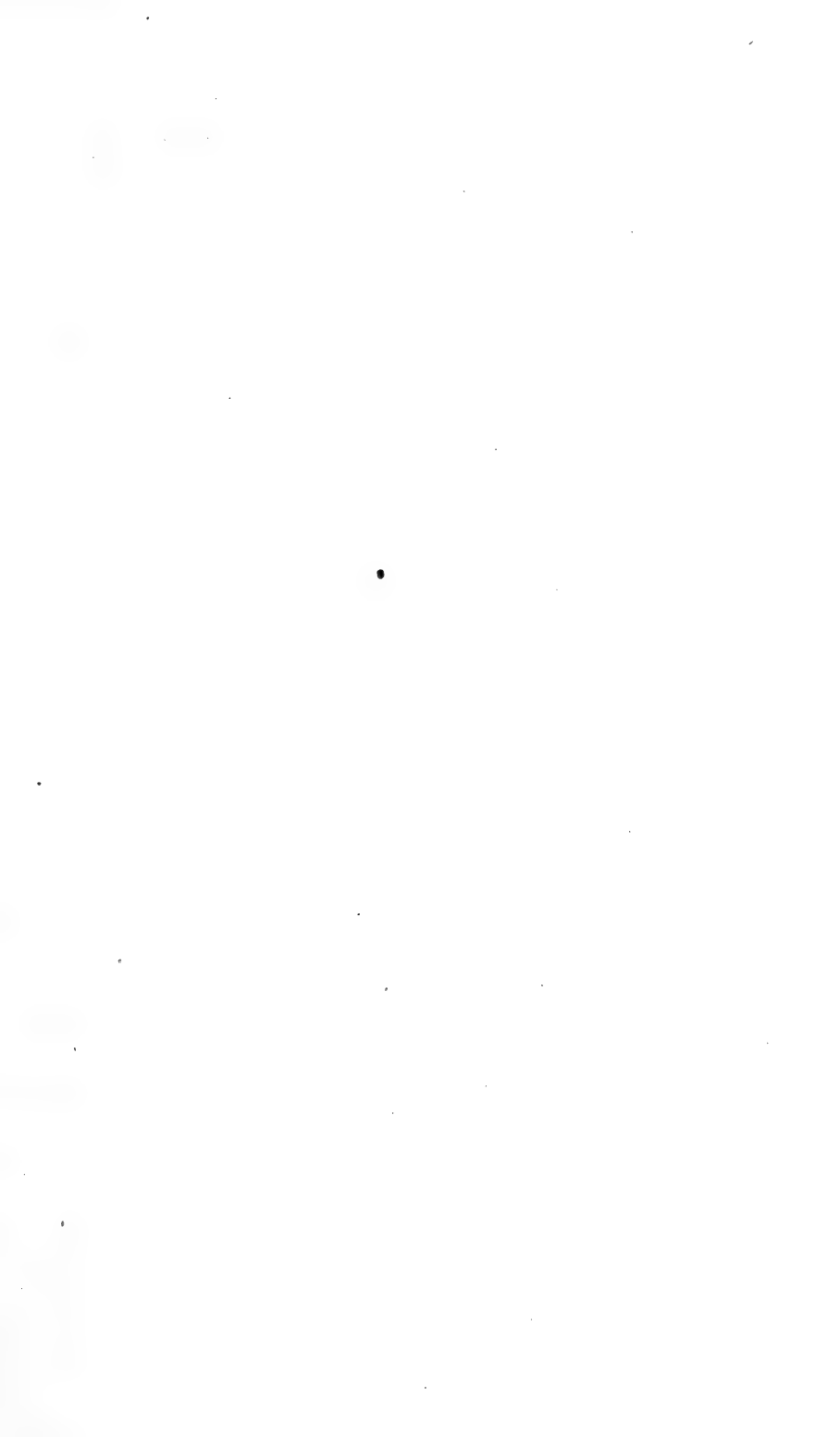
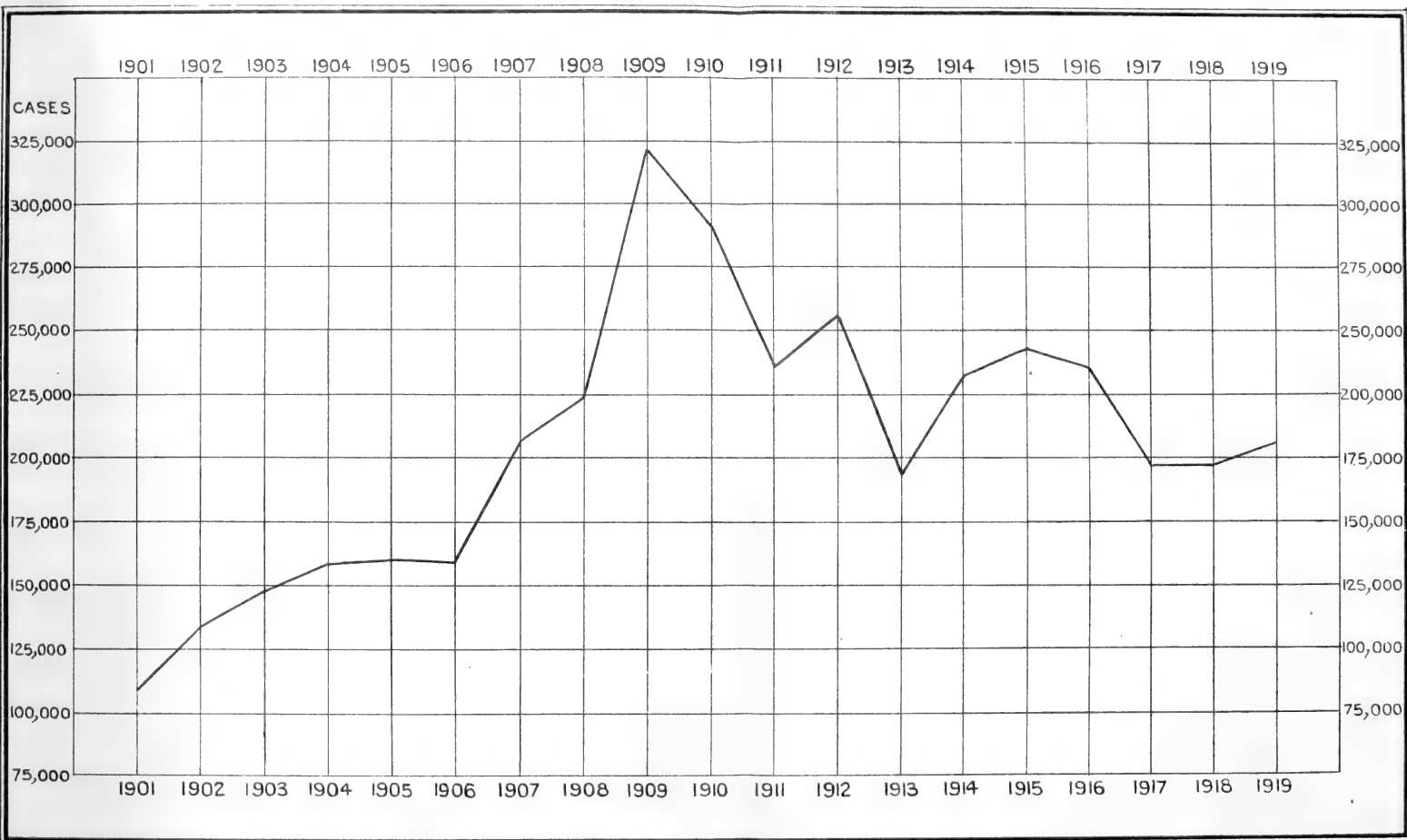




CHART TO SHOW SIX-MONTHLY FLUCTUATIONS IN CALCUTTA PRICES OF  SHELLAC JANUARY 1901 TO JANUARY 1919.



VI
CHART TO SHOW TOTAL EXPORTS OF SHELLAC FROM INDIA DURING EACH YEAR 1901 TO 1919




VII

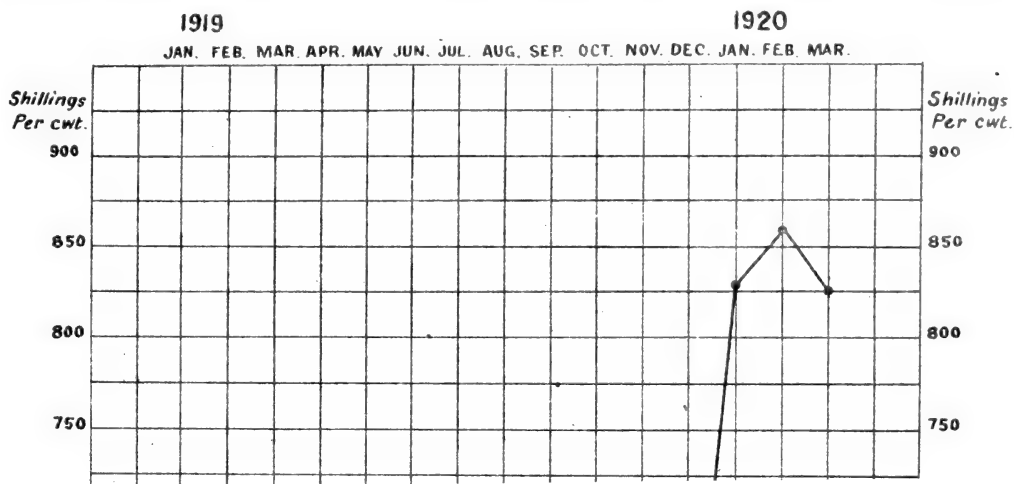
CHART TO SHOW MONTHLY FLUCTUATIONS IN LONDON STOCKS SHELLAC FROM JANUARY 1919.





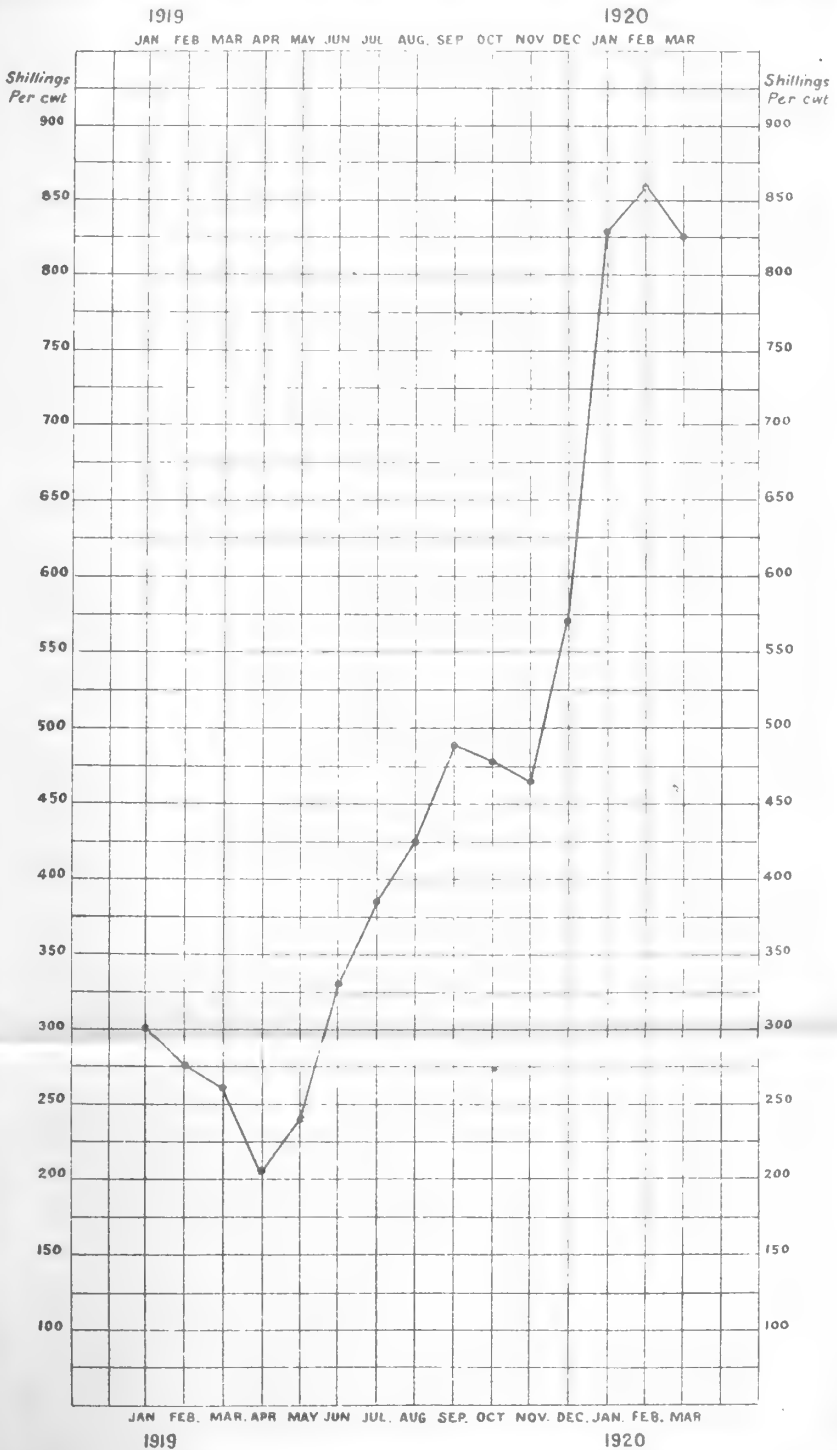
VIII

CHART TO SHOW MONTHLY FLUCTUATIONS IN LONDON PRICES
OF  SHELLAC FROM JANUARY 1919.



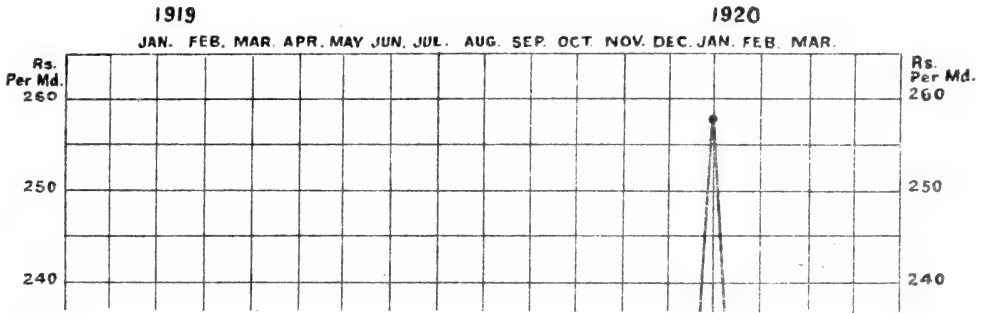
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CHART TO SHOW MONTHLY FLUCTUATIONS IN LONDON PRICES OF  SHELLAC FROM JANUARY 1919.



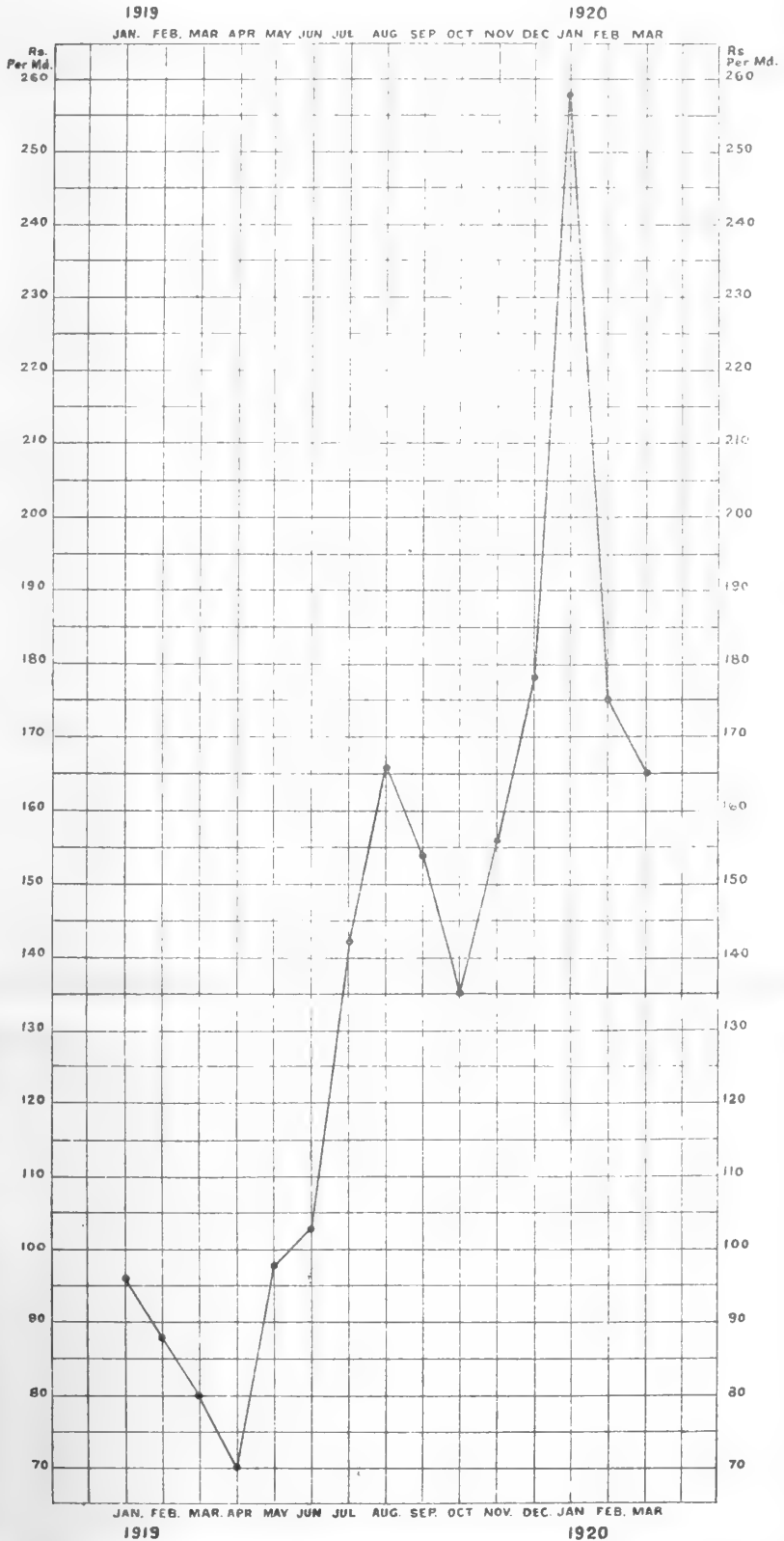
IX

CHART TO SHOW MONTHLY FLUCTUATIONS IN CALCUTTA PRICES
 OF  SHELLAC FROM JANUARY 1919.



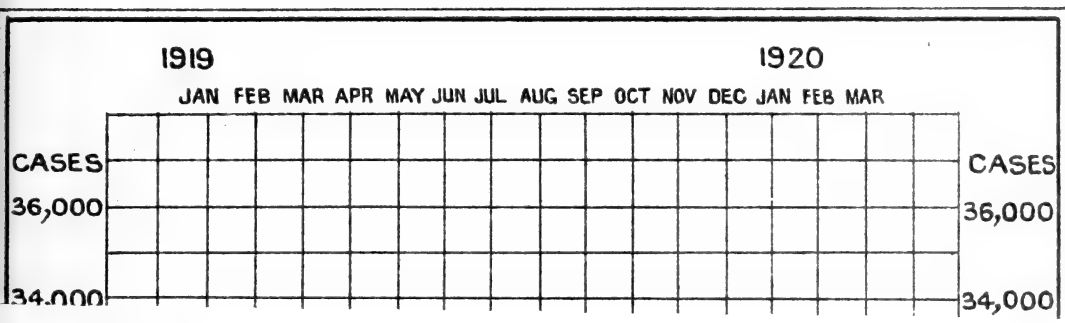
IX

CHART TO SHOW MONTHLY FLUCTUATIONS IN CALCUTTA PRICES
OF  SHELLAC FROM JANUARY 1919.



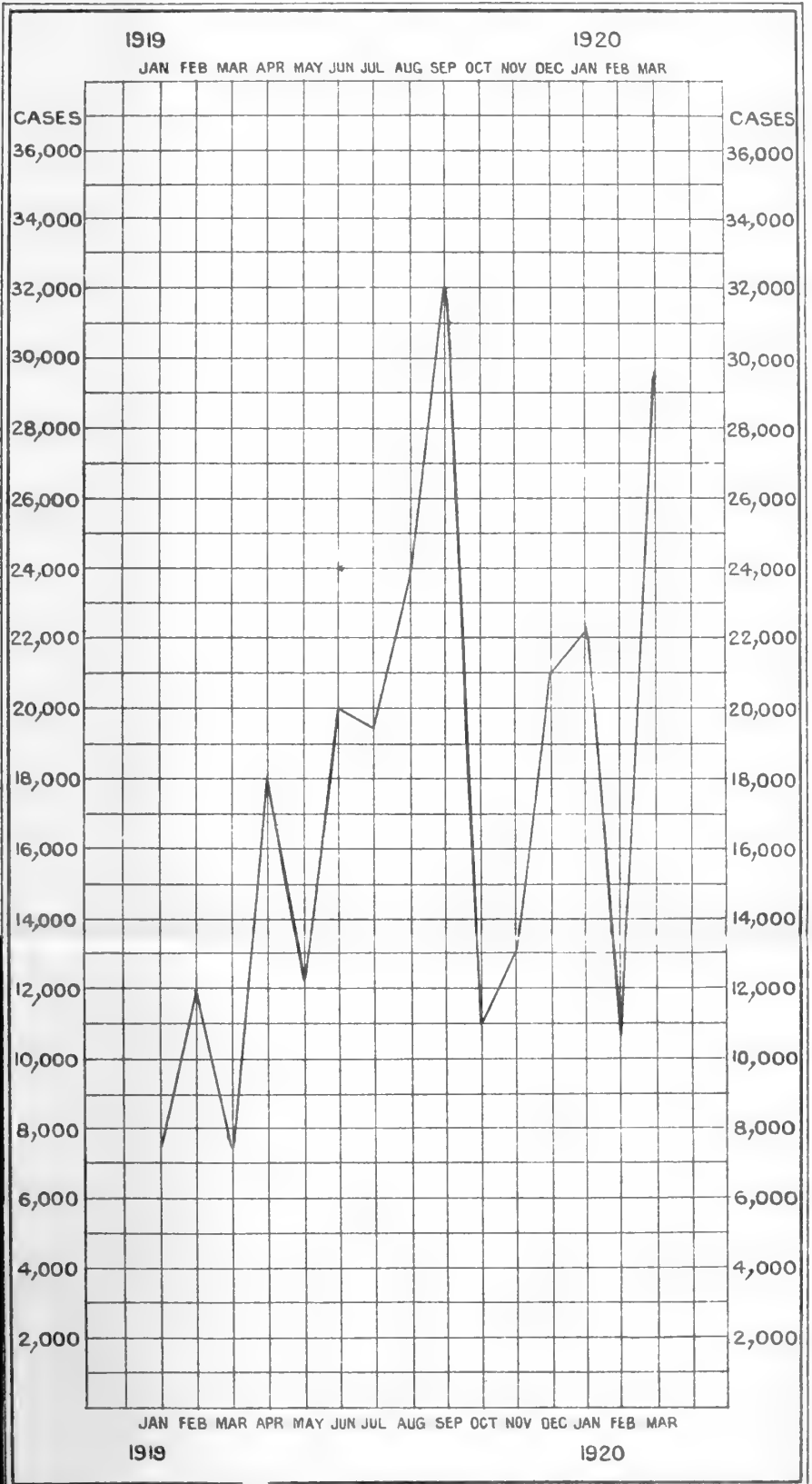
X

CHART TO SHOW TOTAL EXPORTS OF SHELLAC FROM
INDIA DURING EACH MONTH FROM JANUARY 1919

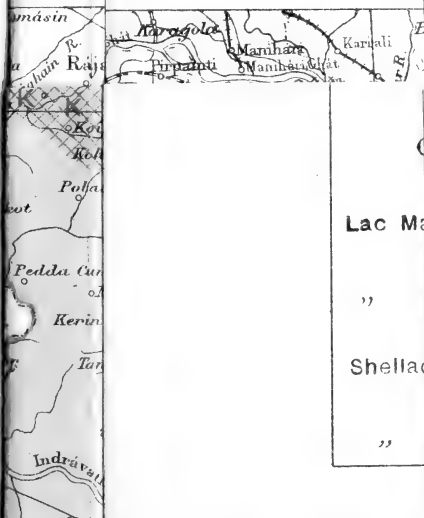


X

CHART TO SHOW TOTAL EXPORTS OF SHELLAC FROM INDIA DURING EACH MONTH FROM JANUARY 1919



88°



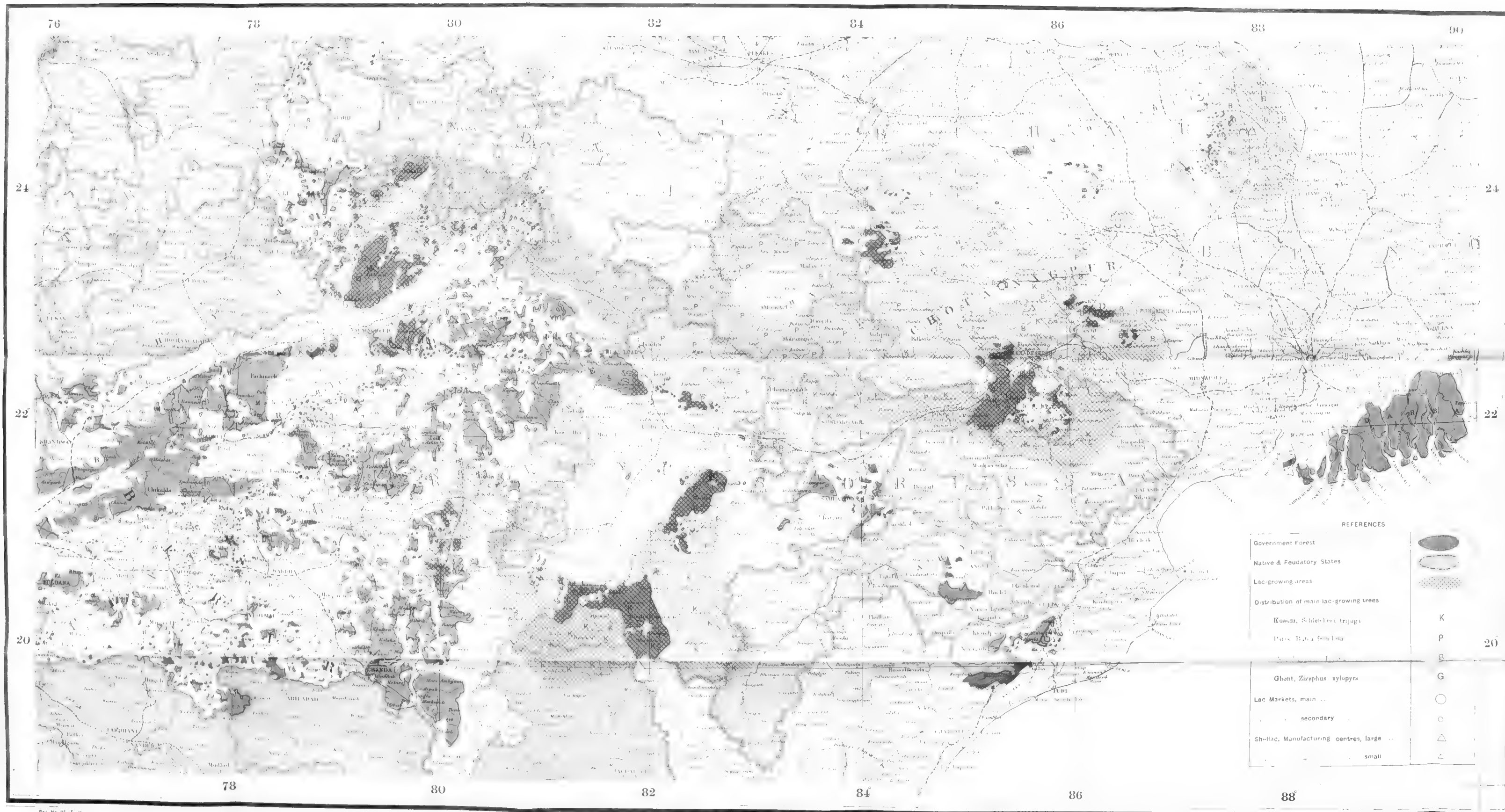
Lac Ma

”

Shellac

”

MAP OF THE MAIN LAC AREA



Put issued at the request of the Lac Enquiry Officer Department of Commerce, India.
1920

Scale 1 Inch = 32 Miles

M 10 20 30 40 50 60 70 80 90 100 M 10 20 30 40 50 60 70 80 90 100

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Fig. 1.

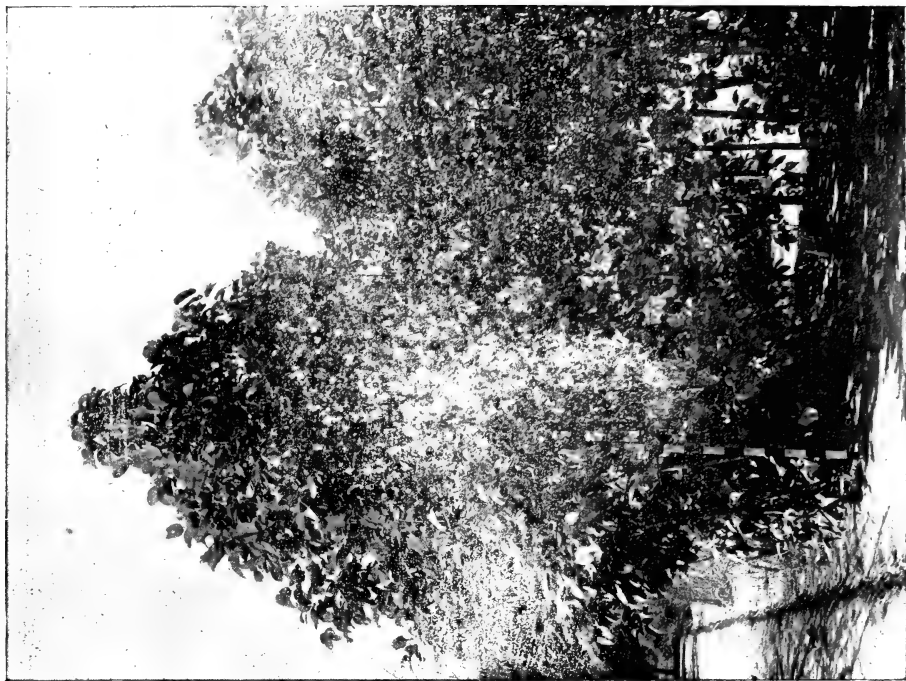


Fig. 2.

Sal plants grown from seed in the Dehra Dun Experimental Garden. Photographed on February 6th, 1919. In Fig. 1 the plants are 5½ years old and in Fig. 2 the plants are 8½ years old. The 6 ft. measuring staff appearing in this and in the subsequent plates shows lengths of 6 inches,

INDIAN FOREST RECORDS

Vol. VIII.]

1920

Part II

The Regeneration of Sal (*Shorea robusta*) Forests.

A Study in Economic Oecology.

by

R. S. HOLE, C.I.E., F.C.H.,

Botanist, Forest Research Institute, Dehra Dun.

CHAPTER I.

General outline of work undertaken.

1. The regeneration of the *sal* forests of northern India is, at present, often a very slow and uncertain business, the seedlings dying back more or less completely for a number of years before they finally produce a vigorous persistent shoot.*

With the object of discovering a method of speeding up the growth of *sal* seedlings, and of quickly regenerating these forests, an oecological study of the factors influencing the development of *sal* seedlings was undertaken at Dehra Dun during the years 1909-19.

The general lines of work adopted were as follows :—

- (1) A series of preliminary experiments was carried out in the Dehra Dun Experimental Garden to test the effect of soil composition, soil moisture, soil aeration and light intensity on the development of the seedlings. The object of these experiments was to obtain an indication as to which of these factors were likely to be most important and the precise effects of such factors on seedling development.
- (2) Seedlings were grown in the local *sal* forests near Dehra Dun in different localities, both in the shady forests and in the open. These experiments were repeated for several years in order to obtain average results, unaffected by excep-

* For examples of such seedlings see *Indian Forest Records*, V, 4, part II, 1916, Plate I.

tionally favourable or unfavourable seasons. The growth of the seedlings was carefully watched throughout the year and, so far as possible, the chief factors were determined by observation which appeared to have most influence in causing the death or bad growth of seedlings at different seasons.

- (3) The effects of such dominant, or limiting, factors were then further tested in the Dehra Dun Experimental Garden, in pot cultures and in water cultures.
- (4) A further series of experiments was run in the local forests with the object of seeing how far the limiting factors could be controlled by methods suitable for incorporation in a practical system of silvicultural management.

Results obtained during the years 1909—15.

2. The work carried out during the years 1909—15 indicated that the chief limiting factors affecting *sal* seedlings were :—

- (1) A layer of dead leaves on the soil surface which is injurious to germination and early development. (*Ind. For. Rec.* V. 4, part II, 1916, pp. 69, 70 and *Indian Forester* XLI, pp. 353, 354, October 1915.)
- (2) Soil moisture, drought being responsible for the widespread death and dying-back of seedlings during the months of short rainfall. (*Ind. For. Rec.* V. 4, part II, 1916, pp. 55, 56, 57, 58.)
- (3) Bad soil aeration. This factor causes a large number of deaths in the shade during the rains and increases the subsequent damage from drought on account of its injurious effect on root development (*l.c.*, part II, 1916, pp. 52, 59, 66).

In the light of these results, it was suggested that the best method of regenerating these *sal* forests probably consisted in :—

- (a) Clearing the surface soil of dead leaves and humus.
- (b) Clear felling in strips and small patches, the width of the former and diameter of the latter being about equal to the height of the surrounding trees.
- (c) Artificial sowing in the cleared areas combined with weeding in the first year.

At the same time it was pointed out that where this method was impracticable, *e.g.* in areas where labour is scarce, the number of seedlings on the ground can be quickly increased merely by the continued removal of the dead leaves by light leaf-fires. (*l.c.*, part II, 1916, pp. 74, 81.)

CHAPTER II.

EXPERIMENTS CARRIED OUT DURING THE PERIOD 1915-1919.

Objects of work.

3. As the system of regeneration suggested above was, to some extent, contrary to existing ideas, it was advisable to obtain further evidence regarding it during a series of years, so that it could not be argued that the good results hitherto obtained were due to exceptionally favourable seasons. Evidence was also required as to the comparative merits of alternative methods of treatment which had been suggested. Finally, further details were needed to determine what may be regarded as the ideal seedling development for the locality and to elucidate the injurious action of a layer of dead leaves on germination and early growth. Work was accordingly continued on these lines during the years 1915-18.

Details of local rainfall.

4. As an indication of the general character of the seasons during the period covered by this work, the following table is given which shows:—

- (1) The average monthly and annual rain-fall at Dehra Dun for the period 1878-1910, and (2) the monthly rainfall during the period June 1909 to January 1919:—

	Jany. In.	Feb. In.	Mar. In.	April In.	May In.	June In.	July In.	Aug. In.	Sept. In.	Oct. In.	Nov. In.	Dec. In.	TOTAL FOR YEAR. In.
Average rainfall for period 1878 to 1910.	2.27	2.33	0.98	0.70	1.48	8.42	27.00	30.55	9.43	0.89	0.30	0.87	85.22
Rainfall in 1909.	..	..	..	..	..	10.32	42.82	42.71	6.03	0.02	..	1.98	..
„ 1910.	1.72	0.98	..	0.74	1.16	5.13	34.55	47.03	12.31	5.24	..	0.23	109.09
„ 1911.	9.05	0.59	7.18	0.21	0.16	10.76	4.39	25.38	15.88	1.70	4.55	..	79.85
„ 1912.	1.96	0.72	0.81	0.48	0.57	5.13	12.53	28.89	9.98	..	1.23	0.44	62.74
„ 1913.	0.17	8.12	2.42	0.06	2.30	17.19	16.77	11.03	0.38	1.39	0.17	1.67	61.67
„ 1914.	0.01	3.28	2.62	2.81	1.27	5.37	25.72	19.89	12.34	1.54	0.18	0.03	75.06
„ 1915.	3.34	4.98	2.63	0.39	1.06	11.92	19.24	34.91	9.25	0.27	—	0.21	88.20
„ 1916.	0.61	1.25	0.02	0.38	1.28	20.64	23.40	29.83	13.26	3.71	..	..	94.38
„ 1917.	0.43	1.32	1.76	1.52	1.79	8.39	39.77	27.72	26.36	6.92	..	1.00	116.98
„ 1918.	0.54	..	1.23	2.17	1.82	8.93	9.46	16.65	4.45	0.31	0.04	0.13	45.73

Analyses of Soils and Acknowledgments.

5. The writer is indebted to Mr. Puran Singh, Chemical Adviser, Forest Research Institute, for the moisture determinations in para. 23 (4) and for the soil analyses given in the Appendix. Samples A and B are of the loam in the Dehra Dun Experimental Garden utilised in Experiment I, samples C—F are of the local *sal* forest loam utilised in Experiments II-VIII and sample G is of the river sand utilised in Experiment II. The writer desires to tender his cordial thanks to Mr. P. H. Clutterbuck, C.I.E., Chief Conservator of Forests, United Provinces, and to Mr. H. G. Billson, Conservator of Forests, for giving him every facility for carrying out, in the local forests, experiments III—VIII reported below. To Mr. Clutterbuck's unique knowledge of the *sal* forests of Northern India the writer is especially indebted for most valuable suggestions regarding the conduct of the experiments.

EXPERIMENT NO. I.

Object to determine the ideal seedling development for the locality.

6. Previous observations indicated that *sal* seedlings grown in the open in the Dehra Dun Experimental Garden, where the soil is kept moist by periodic sub-soil irrigation and where frost does practically no damage, develop vigorously from the first and do not die back.* (*Indian Forest Records*, V, 4, Part II, 1916, p. 44). The present experiment merely consisted in continuing the observations on the development of these seedlings. These observations have supported the previous conclusion that, under favourable conditions of moisture, soil, and light, *sal* seedlings in this locality develop vigorously and continuously from the first and do not die back.

The details of the plants measured are shown below. Plate 1, Fig. 1 shows a group of these *sal* seedlings 5½ years old and Plate I, Fig. 2, a group of seedlings 8½ years old.

Details of plants measured.	Average annual height growth in inches.
(1) 6 plants, two years old, measured July 1912, on an area of 54 square feet, gave an average height of 5 feet 4 inches (4' 5" to 6' 4").	32.0
(2) 10 plants, 5½ years old, measured at beginning of February 1919, on an area of 90 square feet, gave an average height of 14 feet 9 inches (13' 2" to 16' 10").	32.2
(3) 6 plants, 8½ years old, measured at beginning of February 1919, on an area of 54 square feet, gave an average height of 22 feet 3 inches (18' 11" to 29').	31.4

*For examples of such seedlings, one year old, see *Ind. For. Rec.* V, 4, Part II, 1916, Plate II.

It will be seen that the average annual height growth has remained almost constant between the ages of 2 and 8 years and up to a height of 22 feet. Chemical and mechanical analyses of the soil in the Dehra Dun Garden are given in the Appendix, Samples A and B.

EXPERIMENT II.

Object of Experiment. To determine the effect of a layer of dead leaves on germination and early growth of seedlings.

7. In an experiment carried out in 1913 by the writer, it was shown that a layer of dead *sal* leaves in the surface soil is injurious to germination and the development of *sal* seedlings and this was ascribed to bad soil aeration caused by the increased water content and the addition of organic matter to the soil. (*Indian Forester*, XLI, pp. 353, 354, October 1915, and *Ind. For. Rec.* V, 4, Part II, pp. 69, 78, 1916.)

In an experiment carried out in 1914-15, Mr. R. S. Troup also showed that dead *sal* leaves were decidedly injurious, but he attributed the effect mainly to the mechanical action of the leaves (*Indian Forester* XLII, pp. 57-60, 1916).

The present experiment was undertaken with the object of obtaining more definite information regarding these two actions.

The present experiment was divided into 4 parts designated (a) to (d) below.

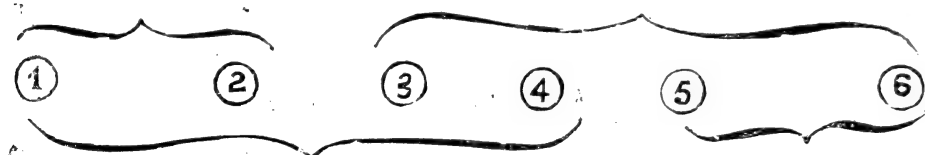
(a) To test the mechanical action of dead leaves.

8. In June 1916, six large porous pots were sunk in the soil, in the open, in the Dehra Experimental Garden so that their upper edges projected one inch above the level of the surrounding soil. Each pot measured 2 feet high and 2 feet in diameter at the top and had three lateral drainage holes at the base each of $\frac{3}{4}$ inch diameter. The pots being sunk and thus brought into close contact with the soil on the sides and at the base, the temperature of their contents would approximate to that of the surrounding soil. On June 8th, 1916, two of these pots (1-2) were filled with clean river sand brought locally from the Song river, and the remaining four pots (3-6) were filled with loam brought from the local Lachiwala *sal* forest. A layer of dead *sal* leaves, 6 leaves thick, was then laid on the surface of the soil in pots 1-4 inclusive. In a well-stocked *sal* forest, the annual leaf-fall forms an average layer 4-5 leaves thick, and below this there is usually a thin layer of raw humus from the previous year's supply. A layer of 6 leaves, therefore, is believed to approximate to that found in the natural forests. On June 20th,

1916, 25 *sal* seeds* were sown in each pot, these being placed on the layer of dead leaves in pots 1-4 and on the surface of the soil (not buried in the soil) in pots 5 and 6. The arrangement is shown below :

Pots with sand

Pots with *sal* forest loam



seed on surface of dead leaves

seed on surface of soil.

All the pots were lightly watered once daily on days when no rain fell.

9. An abstract of the observations recorded is shown below :—

Pot Number.	Sand with dead leaves.		Loam with dead leaves.		Loam without dead leaves.		REMARKS.
	1	2	3	4	5	6	
Date of Sowing	June 20th, 1916.						Those plants are considered to have germinated which have developed a healthy aerial shoot.
Number of seeds sown	25	25	25	25	25	25	
Number of seeds which germinated.	0	0	0	0	12	15	
Number of healthy plants on August 2nd, 1916.	0	0	0	0	11	14	
	Seeds dead.						

This experiment, therefore, shows that the layer of dead leaves has entirely prevented germination not only in the forest loam but also in the well-aerated sand and, therefore, the action in this case is apparently a mechanical one and not an aeration effect.

(b) To further test mechanical action of dead leaves.

10. In the previous experiment it was noticed that several of the seeds on the dry leaves failed to put out a radicle at all, and in others the radicle blackened and withered shortly after emergence from the seed. It appeared probable that the injurious action of the loose layer of dry leaves was due, in part at least, to its forming a hot dry barrier between the soil surface and the seeds, thus cutting off the latter from the moisture necessary for the vitality of the seeds and the continued development of the radicle. In other words, it appeared that the action was

* What are here and elsewhere in this paper called *sal* "seeds," in accordance with ordinary forest phraseology, are of course really "fruits."

primarily one of drought. The experiment was, therefore, continued to test this hypothesis as follows :—

Sixteen pots of the same size as those used in the first part of the experiment were filled with loam brought from the local Lachiwala *sal* forest on July 4th, 1917. Of these pots, 1-4 were placed under the shade of trees and the remainder in the open in the Dehra Garden. On the surface of the soil a layer of dead *sal* leaves, 6 leaves thick, was spread in pots 1-8 inclusive, and 25 *sal* seeds were sown in each pot, these being placed on the layer of dead leaves in pots 1-8, and on the surface of the soil (not buried in the soil) in pots 9-16. After sowing, a layer of dead *sal* leaves 6 leaves thick was placed above the seeds in pots 13-16. The arrangement is shown below :

Under shade of trees	{	①	②*	③	④*	}	Seed on dead leaves.
		⑤	⑥*	⑦	⑧*		
In open	{	⑨*	⑩	⑪*	⑫	}	Seed on surface of soil. No dead leaves.
		⑬	⑭*	⑮	⑯*		
							Seed on surface of soil and then covered with dead leaves.

The pots marked* were lightly watered daily, the remainder were not watered and received the rainfall only. As germination occurred, observations were made regarding the length of time the radicle remained healthy and when it blackened and withered, except in the case of the seeds covered by dead leaves which were only examined on July 20th after the leaves had been removed.

11. An abstract of the observations recorded is shown below :—

Pot Number.	IN SHADE. SEED ON DEAD LEAVES.				IN OPEN. SEED ON DEAD LEAVES.				IN OPEN. SEED ON SURFACE OF SOIL. NO DEAD LEAVES.				IN OPEN. SEED UNDER DEAD LEAVES.				REMARKS.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	watered.		watered.		watered.		watered.		watered.		watered.		watered.		watered.		
Date of sowing	July 4th, 1917.																25 seeds sown in each pot.
Number of seeds with healthy radicles on July 9th, 1917.	23	23	22	24	15	9	9	9	20	20	20	21					
	92				42				81				Not noted.				
Number of seeds with blackened or withered radicles on July 9th, 1917.	2	2	2	1	2	9	10	11	0	0	2	0					
	7				32				2				Not noted.				
Number of seeds with healthy radicles on July 20th, 1917.	0	2	3	3	1	4	1	10*	23	14	9	15*	19	14	16	14	
	8				16				61				63				
Number of seeds with dead radicles on July 20th, 1917.	22	22	22	22	24	20	21	14					4	1	3	1	
	88				79				Not noted.				9				

* It was noticed that surface percolation was distinctly slower in pots 8 and 12 than in the remainder. After rain, water invariably remained on the surface longest in these 2 pots which tended to keep the seeds moist.

On July 9th, the majority of the healthy radicles developed in pots 9-12 had penetrated the soil. The healthy radicles found on removing the dead leaves in pots 13-16 on July 20th had also penetrated the soil.

Chief points to notice.

12. The chief points in this experiment which deserve notice are :—

- (1) On the dead leaves in pots 1-8, the radicles remained healthy longer under the shade of trees in pots 1-4 than in the open in pots 5-8, *vide* the observations on July 9th.
- (2) On the dead leaves in pots 1-8, the radicles remained healthy longer in the pots which were watered, 2, 4, 6 and 8, than in those which were not watered, 1, 3, 5 and 7, *vide* the observations on July 20th. The largest number of persistent healthy radicles in these pots, also, is seen to occur in No. 8, in which the layer of leaves was kept constantly wet owing to slow surface percolation. In this pot, however, the mechanical obstruction afforded by the tough leaves prevented the radicles from penetrating vertically downwards into the soil, and the latter were developed horizontally between the leaves, as is so frequently seen to be the case in the natural forests.
- (3) A layer of dead *sal* leaves *between the seeds and the soil surface* is decidedly injurious to germination and the development of the seedlings both in loam and well-aerated sand as shown by the small number of healthy seedlings, on July 20th, in pots 1-8, as compared with the large number in pots 9-12 on the same date, and also by the results in part II (a) of this experiment above.
- (4) A layer of dead *sal* leaves *above* the seeds is decidedly beneficial in the open, probably because it shades the seeds from the sun and keeps them moist. It will be noticed that such shade apparently renders the seeds independent of artificial watering to a considerable extent, there being 35 healthy seedlings in unwatered pots 13 and 15, as compared with 28 in the watered pots 14 and 16, on July 20th.
- (5) The fact that seeds germinated well under the loose layer of dead leaves does not prove that dead leaves can have no bad aeration effect. The leaves were resting above the large *sal* seeds which, in their turn, were resting on the soil surface. Thus, surrounding the seeds was a large air space in communication with the outer air by means of the interstices between the leaves. Moreover, the large seeds supporting the dead leaves prevented the latter from coming in contact with the moist soil surface and thus, to a great extent, kept them free from soil and soil organisms. The water and air, therefore,

passing through the leaves was probably not deprived of its oxygen by soil organisms and, the leaves being protected from rapid decay, decomposition products could not accumulate.

- (6) Point (2) above indicates that *sal* seeds are particularly liable to damage by drought. This, however, does not imply that submerging the seeds in water is likely to be a good thing. To test this point, in 1918, four large glazed pots were filled with Song river sand, and 2 of the pots were placed under the shade of trees and 2 in the open. On June 24th, 1918, 20 *sal* seeds were placed on the surface of the sand in each pot. Each pot was then filled with clean tap water (the water being sufficient to entirely cover the seeds), the drainage holes at the base of the pots being closed by corks. As the water diminished by evaporation, more water was added so that the seeds were kept constantly submerged. Under these conditions every one of the 80 seeds sown failed to germinate, whereas 25 per cent. of the seed sown similarly on the same sand in adjacent pots in the shade, on the same date, and which were merely lightly watered as usual, without being submerged, germinated successfully.

It is possible that the injury caused by submerging the seeds is due to a temperature effect and that a certain amount of evaporation is necessary from seeds exposed to a high temperature in order to keep the temperature of the seeds below the lethal maximum. The air temperature in Dehra Dun, in July 1918, was unusually high.

- (7) Points (1), (2), and (3) above clearly indicate that in this experiment dead leaves have had a two-fold injurious action, *viz.*:—

- (a) a drought action resulting from the separation of the seeds from the soil surface by a dry layer of leaves.
 - (b) a mechanical action caused by the resistance of the tough leaves to the passage of the radicle downwards, the latter being forced to move horizontally between the leaves, instead of vertically downwards.
- (8) Points (1), (2) and (4) indicate that *sal* seed is especially liable to damage from drought and a high temperature. It is well known that *sal* seed is difficult to keep and that, as a rule, it tends to lose its vitality quickly. It is also known that, unless early and plentiful showers are obtained shortly after the fall of the seeds, the great majority of the seeds in

the forest fail to complete germination successfully. In order to secure the rapid regeneration of the forests it is necessary, as far as possible, to be independent of unfavourable seasons, and it is important that some method of storing the seed should be evolved which would enable us to keep it alive and in good condition until a continuance of showery weather can be insured.

Points (1) and (4), above, illustrate the beneficial effect of merely protecting the seed from the sun* and there is every reason to believe that seed can be stored for several weeks, if necessary, without being seriously damaged. The writer has kept seeds for several days in closed baskets in a cool shady room, and has obtained healthy plants from these, even when the radicle and plumule had both developed strongly and begun to wither back from the tips before sowing. On July 7th, 1917, also, he sent a number of seeds from Dehra Dun to Mr. Burkill at Singapore, which were packed in a wooden box wrapped in stout paper. In letters dated 8th August, 1917, and 30th October, 1917, Mr. Burkill wrote as follows regarding this consignment:—

“I think it quite an achievement on your part to have got the seed here in such a good condition * * * thanks to you I have got a very nice lot of little *sal* plants now.”

This seed had been collected three days before despatch, and was 24 days in transit and had, therefore, been kept for one month before it was sown.

At the time of collecting, the seed should be carefully protected from the sun by being placed in baskets lined with green leaves or otherwise, and the seed should then be stored in a dry, cool, shady place and covered with a layer of dry soil or dry dead leaves. Placing the seed in dry sand and then covering the whole with a layer of dry soil or dead leaves might also be tried. Sowing should be done, as far as possible, on cloudy, showery days.

(c) *To test the aeration effect of dead leaves.*

13. To test the aeration effect of dead leaves on the growth of seedlings, the plan was adopted of spreading a layer of dead leaves on the surface of the soil *after sal* seedlings had become successfully established and had sent their roots well down into the soil.

In June, 1916, four large porous pots, similar to those used in experiment II (a) above, were similarly sunk in the ground in the open in the

* The writer has also found that by just burying the seed in the surface soil, leaving the wings of the fruit exposed above the soil, the percentage of germination is invariably better than when the seed is sown broadcast on the surface of the soil, which appears to support this conclusion.

Dehra Experimental Garden, so that their upper edges projected one inch above the level of the surrounding soil. On June 8th, 1916, the pots were filled with loam brought from the local Lachiwala *sal* forest. On June 20th, 1916, 25 *sal* seeds were sown in each pot, these being placed on the surface of the soil (not buried in the soil). The pots were lightly watered once daily on days when no rain fell. On July 14th, when several healthy seedlings had become thoroughly established in each pot, with their roots in the soil and green leaves fully developed, a layer of dead *sal* leaves, 6 leaves thick, was placed on the surface of the soil in two of the pots. The arrangement is shown below :

(5)

(6)

(7)

(8)

No dead leaves. Dead leaves placed on surface after seedlings established. No dead leaves.

On January 17th, 1917, the seedlings were carefully removed from the soil and their roots measured.

14. The following is an abstract of the observations recorded :—

Pot Number.	No dead leaves.	Layer of dead leaves on surface of soil.		No dead leaves.	REMARKS.
	5	6	7	8	
Number of healthy seedlings on July 14th, 1916.	12	15	13	12	25 <i>sal</i> seeds were sown in each pot on June 20th, 1916. A layer of dead <i>sal</i> leaves, 6 leaves thick, was placed on surface of soil in pots 6 and 7 on July 14th, 1916.
Number of healthy seedlings on August 12th, 1916.	12	12	10	12	
Number of sickly seedlings on August 12th, 1916, with leaves shed or turning brown.	0	3	3	0	
Healthy seedlings on November 8th, 1916.	12	10	3	12	
Sickly seedlings with leaves shed on November 8th, 1916.	0	4	7	0	
Seedlings dead on November 8th, 1916.	0	1	3	0	
Average length of root of living plants on January 17th, 1917, in inches.	2.4	2.1	0.8	3.8	

Result.

15. The above details indicate that placing dead *sal* leaves on the soil surface has had a decidedly injurious effect on the early development of *sal* seedlings in increasing the number of deaths, and in materially retarding the root-growth. This injurious action is provisionally ascribed to a bad soil-aeration effect, but further work is required to prove this ; and also whether the effect is due to a deficiency of oxygen (caused by

interference with the passage of oxygen into the soil and by the activity of soil organisms accelerated by the increased moisture and addition of organic matter), or to the accumulation of decomposition products.

(d) *To further test the aeration effect of dead leaves.*

16. If the injurious action of dead leaves noted in the last experiment is really a bad aeration effect, we should expect it to be less operative in clean sand than in the forest loam.

In a clean sand containing little organic matter, the activity of soil organisms would be less with consequently less consumption of oxygen and production of decomposition products than in a forest loam rich in organic matter. In the former, also, more rapid percolation would allow fresh oxygen supplies to penetrate more rapidly, and decomposition products to be dissipated more quickly than is possible in the latter. A previous experiment (*Ind. For. Rec.* V, 4 Part II, pp. 67-72, 1916) had already indicated that in such a sand a layer of dead *sal* leaves, 6 leaves thick, had a beneficial rather than an injurious effect on the development of *sal* seedlings, inasmuch as it increased the soil water content and diminished the damage from drought. The present experiment was undertaken with a view to checking these results and those of experiment II (c) above.

17. On August 20th, 1917, 13 pots of the same size as those used in the previous experiments were selected, in which a number of healthy *sal* seedlings had become established from seeds sown at the beginning of July 1917. These seedlings had well-developed green leaves, and had sent their roots well down into the soil. Six of the pots contained loam brought from the local Lachiwala *sal* forests, and the remainder clean river sand brought locally from the Song river, and all the pots were placed in full sun-light, in the open, in the Dehra Dun Experimental Garden. On August 20th, 1917, a layer of dead *sal* leaves, 6 leaves thick, was placed on the surface of the soil in 3 of the loam pots and on the surface of the sand in 3 of the sand pots, and this layer of leaves was renewed on June 3rd, 1918. All the pots were lightly watered once daily on the days when no rain fell. The experiment was continued for $1\frac{1}{2}$ years, and was closed in February 1919 when the surviving plants were carefully washed out of the soil and their roots measured. In the pots which contained a considerable number of living plants at the close of the experiment, several of these had become more or less suppressed by the more vigorous plants and the average root length, therefore, was obtained by measuring the roots of the 6 best plants in each pot. In pot 27, only 5 plants were available for measuring.

18. An abstract of the observations recorded is given below :—

Pot Number.	FOREST LOAM.									REMARKS.
	No dead leaves.			Layer of dead <i>sal</i> leaves placed on surface of soil on August 20th, 1917.						
	12	15	18	11	14	19				
Number of healthy seedlings at beginning of experiment on August 22nd, 1917.	14	16	21	18	20	19				Pots 11 and 12 were porous pots which were sunk in the soil, so that their upper edges projected one inch above the level of the surrounding soil. The remaining pots were glazed and non-porous and were not sunk.
	51			57						
Number of living seedlings in February 1919, at close of experiment.	11	16	20	8	7	8				
	47			23						
Percentage of deaths during experiment.	7.8			59.6						
Average length of root of survivors in February 1919 in inches.	9.3	14.2	16.4	6.0	11.0	10.3				
	13.3			9.1						

Pot Number.	SAND.										
	No dead leaves.				Layer of dead <i>sal</i> leaves placed on surface of soil on August 20th, 1917.						
	22	24	25	27	23	26	28				
Number of healthy seedlings on August 22nd, 1917.	17	14	7	5	17	11	13				All the sand pots were glazed non-porous pots and were not sunk in the soil.
	43				41						
Number of living seedlings in February 1919.	9	7	7	5	8	10	11				
Percentage of deaths during experiment.	28				29						
	34.9				29.3						
Average length of root of survivors in February 1919 in inches.	8.9	15.8	14.0	11.8	12.8	18.3	16.1				
	12.6				15.7						

19. The chief points of interest are as follows :—

- (1) About 3 months after the dead leaves had been placed in position, *i.e.* on November 24th, 1917, the injurious effect of the dead leaves had become apparent in the appearance of the seedlings in loam pots 11, 14 and 19 which were looking decidedly less healthy than those in pots 12, 15 and 18, many of them having shed their leaves. At the beginning of January 1918, *i.e.* about $4\frac{1}{2}$ months after the dead leaves had been put in position, the majority of the seedlings had lost their leaves in pots 11, 14 and 19, while those in pots 12, 15 and 18 were quite healthy. At this time, the seedlings in the sand pots were quite healthy both in the pots with

dead leaves and in those without dead leaves. Plate II Fig. 1, shows the plants in loam pots 15, 18, 14 and 19 on December 4th, 1917 and Plate II Fig. 2 shows the plants in sand pots 22 and 23 on the same date.

- (2) In the forest loam in pots 11, 14 and 19, the layer of dead *sal* leaves has had a decidedly injurious effect in increasing the number of deaths and reducing the root-growth, whereas in the sand pots the effect of the dead leaves has been rather beneficial in both respects.

Summary of Conclusions.

20. The observations recorded above justify, it is believed, the following conclusions:—

- (1) The results previously obtained by Mr. R. S. Troup and the writer have been confirmed, and it has been shown that a layer of dead leaves on the surface of the soil has a decidedly injurious effect on germination and the early growth of *sal* seedlings, the injurious action being three-fold:
 - (a) A drought action, owing to the dry barrier separating the seed from the soil surface, which causes the death of the seed either before, or shortly after, germination has commenced, *see paras. 9, 10, 11 and 12 (1) (2) (4) (8).*
 - (b) A mechanical action due to the obstruction afforded by the tough leaves to the passage of the radicle. When moisture and temperature, therefore, are suitable for the continued growth of the radicle, the latter instead of penetrating vertically downwards into the soil develops horizontally between the layers of leaves. In consequence of this the plants inevitably die from drought so soon as the dead leaves and surface soil dry out, *see para. 12 (2).*
 - (c) An injurious action which comes into play after the radicle has penetrated the soil, and which is provisionally ascribed to a bad soil-aeration effect. It directly causes an appreciable number of casualties, and also diminishes root-growth. It is active in *sal* forest loam which is kept moist but is inoperative in clean sand. How long this action is capable of retarding growth remains to be determined by future work, it is possible that it is chiefly injurious to young seedlings which have their delicate young roots in or near the soil surface, *see paras. 14, 15, 18, 19.*
- (2) *Sal* seeds are especially liable to damage by drought. By care in storage, by keeping them shaded, cool and by prevent-

ing them from drying out, their vitality remains unimpaired for several weeks, *see* para. 12 (8).

- (3) *Sal* seeds which are kept immersed in water fail to germinate, *see* para. 12 (6).

EXPERIMENT No. III.

Object to determine comparative development of seedlings under shade and in the open.

21. The usually accepted principle in the past has been that *sal* should be regenerated under shade. As this is contrary to the method now recommended, *see* paras. 2, 3, above, it was obviously desirable to obtain definite evidence regarding the comparative development of seedlings under shade and in the open respectively. The present experiment was undertaken to provide this evidence. The experimental plots IV and V dealt with in this experiment are the same as those for which the results up to the year 1915 have already been published (*Ind. For. Rec.* V, 4 Part II, 1916, pp. 74-77), and the present experiment has merely consisted in continuing the previous observations. For convenience of reference, the history of the plots is recapitulated below : Plots IV and V were originally selected in the Lachiwala *sal* forest in 1912, and are only 46 yards apart. The light intensity in the two plots, determined with a Clements's photometer in September 1912, was 0.02 in plot IV and 0.06 in plot V. The ground was cleared of humus and *sal* seeds were sown in dug soil, in 1912, in both plots under shade, all standing trees and saplings being left untouched. The result was practically a complete failure in both plots but was slightly better in plot V, with 4 per cent. surviving seedlings in April 1913, than in plot IV with no living seedlings on that date (*l.c.* pp. 48-52). The object of the present experiment was to repeat the sowings in both plots after removing the overhead shade in plot IV, and then to compare the development of the seedlings growing with full overhead light in plot IV with that of the plants growing under shade in the adjacent plot V. The surviving plants in the plots were dug up in May 1913, and the central bed in each plot was again prepared for sowing and kept clear of dead leaves. At the end of May 1913, the overhead cover was removed above plot IV by felling all the trees above and in the immediate neighbourhood of the plot, the total cleared space having a diameter of 60 feet, or a little less than the height of the surrounding trees. The light intensity which was 0.02 in plot IV in 1912 was in this way raised to 0.2 in 1913, *i.e.* the light intensity was increased tenfold. The area of the bed sown in each plot was 18 feet \times 3 feet, but as the treatment in plot V varied in the two halves of the bed, the observations recorded are noted below

separately for the two halves of each bed, each such area thus being 9 feet \times 3 feet.

To test the effect of burning off the dead leaves on the seedlings in the shade, a layer of dead *sal* leaves, 6 leaves thick, was laid on the surface of the soil in the eastern half of the bed in plot V and burnt off in June 1916. At the same time, a similar layer of leaves was spread on the surface in the western half of the bed and left intact. The annual fall of dead leaves was removed by brushing from both halves of the bed in 1912, 1913, 1914, 1915, 1917 and 1918.

The bed in plot IV was hand-weeded during the first rains, but after this weeding was unnecessary.

22. An abstract of the observations recorded is given below:—

Plot.	PLOT IV. OVERHEAD COVER REMOVED, DIAMETER OF CLEARING 60 FEET. LIGHT INTENSITY 0.2.		PLOT V. OVERHEAD COVER MAINTAINED. LIGHT INTENSITY 0.06.		REMARKS.
	Northern half of bed 9 feet x 3 feet.	Southern half of bed 9 feet x 3 feet.	Eastern half of bed 9 feet x 3 feet. Layer of dead <i>sal</i> leaves, 6 leaves thick, burnt off in June 1916.	Western half of bed 9 feet x 3 feet. Layer of dead <i>sal</i> leaves, 6 leaves thick, left on surface in June 1916.	
Date of Sowing	June 24th, 1913.				All percentages are calculated on the number of seeds sown.
Number of seeds sown	200	200	200	200	
Percentage of healthy plants at end of 2 years on July 8th, 1915.	59		34		In calculating the average height and root diameter the best plant per 9 square feet of area has been selected.
Average height of plants on July 8th, 1915, in inches.	19.9		8.2		
Percentage of healthy plants in April 1916.	..	..	26	23	
Average height of plants in inches in April 1916.	....	..	9.3	9.8	
Percentage of healthy plants in July 1916 after burning leaves in east half of bed in plot V..	..	..	14	13	
Average height of plants in inches in July 1916.	..	..	6.0	10.8	
Percentage of healthy plants after 5½ years in January 1919.	22	39	8	7	
	30.5		7.5		
Average height of plants in inches in January 1919.	65	43.9	8.3	10.6	
	54.5		9.5		
Average diameter of base of root in inches in January 1919.	..	..	0.2	0.2	
			0.2		

The appearance of the plants surviving in these plots when 2 years old in July 1915 is shown in Plate III. The appearance of the surviving plants when $5\frac{1}{2}$ years old in January 1919 is shown in Plate IV.

23. The chief points of interest in this experiment are :—

- (1) The year 1913 in which this experiment was commenced was an unusually favourable one for *sal* seedlings. Rain during June and July was well distributed and not excessive, while a light rainfall in August and a dry September tended to prevent damage from bad soil-aeration. The total rainfall was unusually light, being only 45 inches during June to September, as compared with the normal rainfall of 75 inches.

The rainfall during June to September 1914 was also less than usual, being only 63 inches instead of the normal 75 inches. From 1915 to 1917, however, both years inclusive, the rainfall for this period was either normal or more than normal.

- (2) The southern half of Plot IV received more shade from the sun during the middle of the day than the northern half; and it was noticed that, at first, during the years of short rainfall the growth in this southern half was decidedly the best. This can be seen in the photograph Plate III Fig. 1. After the normal rains of 1915, however, the growth in this part of the bed steadily deteriorated. The statement given above shows that, in 1919, the height-growth in the southern half was less and the number of surviving plants greater, owing to the fact that the growth of the stronger plants had not been sufficiently vigorous to kill out the others by suppression, as was the case in the northern half. The poorer growth can also be seen in the photograph, Plate IV Fig. 1. The effect of this shade on the south was to keep the soil perpetually moist which, in years of normal rainfall, caused the plants to suffer from a badly aerated soil and also from the attacks of twig, and leaf-killing fungi. The extra wetness of the soil was obvious to the eye, and was also indicated by a dense growth of mosses and liverworts on the soil surface which finally gave way to a vigorous growth of ferns. Note the strong growth of ferns in the southern half of the bed in January 1919, Plate IV Fig. 1.

- (3) It was noticed that, during the rains, the soil of Plot IV in the open remained, on the whole, drier than that of the shade

Plot V owing to the fact that, during short breaks in the rains, the soil of Plot IV dried out, whereas that under heavy shade in Plot V remained continuously wet. On the other hand, during the cold and dry season, the soil of Plot IV remained much moister than that of Plot V, owing to the much heavier deposition of dew in the former, the subsequent evaporation of which was retarded by the side-shade. Also, in the case of light showers of rain, the rain was able to reach the soil of the open plot unimpeded but failed to moisten the soil under shade to the same extent, much of it being evaporated from the leaves, branches and boles of the trees. The net result was very obvious, *viz.*, that whereas, during the cold and early dry season, the soil of Plot IV in the cleared patch remained constantly moist, that of Plot V in the shade remained comparatively dry.

- (4) The general differences in soil moisture drawn attention to above are illustrated by the following determinations of water in the upper foot of the soil of the two plots, carried out on samples collected on the dates shown :

Plot.	PLOT IV, OVERHEAD COVER REMOVED.		PLOT V, OVERHEAD COVER MAINTAINED.		REMARKS.
	Northern half of bed.	Southern half of bed.	Eastern half of bed.	Western half of bed.	
Percentage of water in soil in :—					
upper 6 inches . . .	27.2	28.4	30.0	30.5	} Samples collected after 2 days fine weather on June 21st, 1915, subsequently to setting in of rains.
lower 6 inches . . .	26.1	27.0	26.5	26.8	
upper 6 inches . . .	18.4	20.5	9.3	10.1	} Samples collected during a spell of hot dry weather on April 7th, 1916.
lower 6 inches . . .	21.9	22.3	14.3	13.6	

It will be seen that, whereas there is comparatively little difference in the water content of the soil in the two halves of Plot V in the case of the soil of the southern part of Plot IV the

water content is uniformly higher than that of the northern half. Also that, subsequently to the setting in of the rains in June 1915, after an interval of 2 fine days, the upper 6 inches layer of soil is distinctly drier in the open plot IV than it is in the shade plot V. On the other hand, during a spell of hot dry weather in April 1916, the upper 1 foot of soil in open plot IV is very much moister than that of shade plot V*. The main factors, therefore, responsible for the much better growth in the open plot No. IV, as compared with that of the shade plot No. V, appear to be :

- (a) Improved soil-aeration and consequently stronger root-growth during the rains, owing to the partial drying out of the soil during the intervals of hot sunshine.
 - (b) Moister soil, owing to dew and light showers, during the cold and dry season, which reduces the danger of damage from drought.
- (5) The northern half of Plot IV shows that clearing the overhead cover in a patch 60 feet in diameter, has resulted in the production of vigorous established *sal* seedlings which have attained a height of practically $5\frac{1}{2}$ feet in $5\frac{1}{2}$ years.
- (6) Taking the whole of Plot IV together, we get an average height-growth of 55 inches in $5\frac{1}{2}$ years or 10 inches per annum, which is the same as that calculated in 1915, thus showing that the average annual height-growth has remained practically constant throughout the period of the experiment.
- (7) Burning off the dead leaves in the eastern half of plot V has apparently not decreased the number of surviving seedlings (compare 8 per cent. survivors in eastern half with 7 per cent. in western). It has, however, apparently weakened the plants. All of the stems being burnt back in June 1916, there was a sharp drop in the height-growth from 9.3 inches in April 1916 to 6.0 inches in July 1916, and the height-growth in 1919 was only 8.3 inches against 10.6 inches in the unburnt western area ; whereas, before the burning in April 1916, the height was almost equal in the 2 areas, viz. 9.3 inches and 9.8 inches.

* See also para. 57 (14) (16) (18) (19) (20) below.

- (8) The plants in the western half of Plot V are believed to have developed under the most favourable conditions which are possible under shade. Working the soil and removing the annual crop of dead leaves in these forests has been found to improve materially seedling development, and in this case the soil was dug and the humus removed twice before the seed was sown in 1913. Again, during the $5\frac{1}{2}$ years of the experiment, the annual crop of dead leaves was removed from the plot every year, with the only exception of 1916 when the leaves were left to decay on the surface. The seed, also, was sown in 1913 which was one of the most favourable seasons possible, with frequent showers throughout June and July to facilitate germination and a dry September to improve the soil-aeration. There is no doubt that these conditions are more favourable than we are usually likely to secure on a large scale in our forests. That this is the case is also indicated by the fact that, in this small area, two of the seedlings surviving in January 1919 had never died back, and showed a height-growth of 9 inches and 12.25 inches (this was much the best plant in the whole area) respectively, which is quite exceptional for these forests. Notwithstanding these favourable conditions, however, the results are obviously extremely poor, with the number of surviving seedlings steadily diminishing from year to year, with only 7 per cent. survivors after $5\frac{1}{2}$ years and with an average height-growth of only $10\frac{1}{2}$ inches after $5\frac{1}{2}$ years. It will be noticed that the height-growth at present is almost stationary with an average of 10.8 inches in July 1916, and 10.6 inches in January 1919, in the unburnt western portion of Plot V. This is due partly to the death of individual plants, and probably in part to the dying back of the shoot in others.
- (9) In (6) above, it has been shown that the average annual height growth of seedlings in this locality is fairly constant up to a height of about 5 feet. (In para. 6 above, it has been shown that, in the Dehra Dun Garden, this remains fairly constant up to a height of 22 feet.) It is, therefore, possible to estimate the period likely to be required for the establishment of seedlings of any particular size under shade from the measurements of the $5\frac{1}{2}$ year old plants in Plot V. The two plants in Plot V which had not died back showed a height-growth of 9 inches and 12.25 inches, respectively, giving an average

of 10.6 inches in $5\frac{1}{2}$ years. This would give a shoot of 5 feet in 31 years. It is, however, quite exceptional in these forests to find vigorous plants of this kind which have never died back and this rate of growth is almost certainly too fast for the average plant in the shade. It is possible to get an idea of the correctness or otherwise of this estimate by comparing the root-growth of the $5\frac{1}{2}$ -years old plants in Plot V with that of existing young plants in the forest which have already established themselves naturally. Twenty natural "seedlings" dug at random, in January 1919, in the forest immediately adjacent to Plot V, which had a shoot 5 feet high, showed the average diameter of the base of the root to be 1.6 inches (from 1.1 inches to 2.7 inches). The diameter of the base of the root of the $5\frac{1}{2}$ -years old plants in Plot V was remarkably constant, *viz.* 0.2 inch, both of those plants which had never died back and also of those which had died back. Thus it apparently will take 44 years for these plants to attain a root-diameter of 1.6 inches and to produce a shoot 5 feet high. We thus have

(a) Years required for a 5 feet shoot in the shade calculated from the shoot growth of plants which have never died back	31
(b) Years required for a 5 feet shoot in the shade calculated from the root growth of plants which have died back	44
	—
AVERAGE	37.5

Seeing that, in the shade, the great majority of the seedlings do die back (in the western half of Plot V only 14 per cent. of the plants did not die back, and this too under unusually favourable conditions), we are almost certainly on the safe side in adopting 40 years as the period necessary for the production of a shoot 5 feet high in the shade. This would give an average annual height-increment of 1.5 inches.

- (10) To determine the possibility of securing *sal* regeneration naturally under shade and the length of time required for this, it is obviously necessary to consider not only the rate of growth, which has been dealt with above, but also the time required to obtain a full stock of seedlings.

It is believed that an area in the shade cannot be regarded as fully stocked unless there is at least 1 seedling, 10 inches high,

per square foot of area*. The present experiment has shown that the result of one complete sowing is 30 such plants in 54 square feet, which gives a ratio of 0.6 plant per square foot or about half the total number required. Thus, even under the very exceptional conditions of an unusually favourable season for germination and early growth, with the seeds buried in the surface soil and not sown broadcast, and with the soil thoroughly dug and free of raw humus, it would apparently require at least two exceptionally good seed years to give a full stock of seedlings. The combination of an unusually favourable season with an exceptionally good seed year would be very rarely attained, and there is no doubt that the above figures are far too favourable for us to base upon them an estimate of the probable average results to be expected from natural regeneration. It will be noted that in Plot V, of the plants existing at the end of the 2nd year only about $\frac{1}{4}$ survived to attain 10 inches in height at the end of the 5th year (34 per cent. survivors in 1915 and 8 per cent. survivors in 1919), hence we ought to aim at getting 4 plants per square foot at the end of the second year, if we wish ultimately to obtain 1 plant, 10 inches high, per square foot.

In experiments VI, VII and VIII below, it is shown that, on an average of three years' work in 1916-1918, one heavy broadcast sowing in the shade, on soil which has been dug after being freed of dead leaves, results in only 0.1 plant per square foot of area surviving after 1 to $1\frac{1}{2}$ years. Thus 40 such sowings would be required to produce a full stock of seedlings (4 plants per square foot) and the period required to obtain these, therefore, is 40 years. As this calculation of 40 years has been based on the favourable conditions of a dug soil free of dead leaves, and a full supply of seed annually, it is believed that it may be safely accepted as the minimum period permissible.

After 40 years, then, we may expect a sufficient stock of seedlings on the ground, the average age of which will be 20 years with an average height of 30 inches.

* If the development of a full crop of young *sal* seedlings is watched, it is usually found that the plants which survive and are most vigorous at any particular stage of growth, at any rate up to a height of 3-4 feet, are separated from one another by an average distance roughly equal to their height.

It is thus necessary to add 20 years to the time calculated from the rate of growth of seedlings, in order to obtain the period necessary for a full stock of seedlings of any particular size exceeding a height of 30 inches. Thus, for seedlings 5 feet high, 40 (accepting the annual height increment of 1.5 inches calculated as shown in the last sub-paragraph) $+20=60$ years will be required and for seedlings $3\frac{1}{2}$ feet high $\frac{42}{1.5} + 20=48$ years will be required.

Summary of Results.

24. The details given above are summarized below :—

- (1) By sowing in a cleared patch, the diameter of the patch being 60 feet and somewhat less than the height of the surrounding trees, vigorous *sal* seedlings averaging 55 inches high have been established in $5\frac{1}{2}$ years, with 31 per cent. of plants surviving at the end of the period (calculated on the number of seeds sown), *see* para. 22.
- (2) Similar sowings carried out simultaneously under the shade of the adjacent forest have resulted in only 8 per cent. of survivals with an average height of 10 inches, *see* para. 22.
- (3) From measurements of the seedlings of known age produced in the open and in the shade, respectively, and from a consideration of the dimensions of naturally established plants, it is estimated that a full stock of seedlings 5 feet high can be produced by artificial sowings in a cleared patch in 6 years, whereas, by natural regeneration in the shade, a period of not less than 60 years is required to produce a similar stock of seedlings of the same height, even when germination is assisted by clearing the dead leaves from the surface soil and when a good supply of seed is annually available, *see* para. 23 (6) (9) (10).
- (4) The greatly superior results obtained in the cleared patch are mainly due to two factors :—
 - (a) Improved soil-aeration and consequently stronger root-growth during the rains, owing to the partial drying out of the soil during the intervals of hot sunshine.
 - (b) Moister soil, owing to dew and light showers, during the cold and dry season which reduces the danger of damage from drought, *see* para. 23 (3) (4).
- (5) In years of short rainfall, side shade on the south in the cleared patches is beneficial, but in years of normally heavy rainfall side shade on the south is injurious, *see* para. 23 (1) (2).

- (6) Burning off the soil covering of dead leaves in the forest does not decrease the number of surviving seedlings but reduces their height-growth *see* para. 23(7).

EXPERIMENT NO. IV.

Object to test the advantages of starting seedlings under shade and then opening the cover.

25. It has been suggested that, in order to avoid the danger of a heavy weed growth, it may be advisable to start the seedlings under shade and to open the overhead cover only when a sufficient stock of seedlings is already on the ground. The object of the present experiment was to test the advantages or otherwise of this procedure. The areas utilized in this experiment were beds (2) and (3) in Plot VI (*see Ind. For. Rec.* V, 4, Part 2, 1916, pp. 61, 73 and Plate IV) which is a shade plot similar to plot V dealt with in the last experiment, and from which it is only 39 yards distant. The light intensity was 0.05 as compared with 0.06 in Plot V.

26. The work done and observations recorded are as follows :—

Plot Number.	PLOT VI.		REMARKS.
	(2)	(3)	
	Humus removed 2 years and the last time by burning, soil once dug before sowing.	Humus removed 2 years by brushing and soil once dug before sowing.	
Light intensity Date of sowing	0.05 June 24th, 1913.		(a) From this bed 50 plants had been previously removed for examination; of these, 7 plants would probably have survived, thus making the probable number of survivals in this plot 36 in April 1916 instead of the 29 actually existing. This is on the assumption that the mortality among the 50 plants removed would have been proportionate to that among the rest of the plants.
Number of seeds sown Number of healthy plants in April 1916.	400 48	400 29 (a)	
Height of plants in April 1916 in inches.	1.75 to 9.5	3 to 10.5	
Work done May 10th to 16th, 1916.	All standing trees and shrubs felled and overhead cover completely removed from the plot in a patch 60 feet in diameter.		
Work done June 13th, 1916	All dead leaves removed from plot by brushing (b)		
Work done June 13th, 1916	Soil not hoed	Soil around the plants hoed.	(b) The annual leaf-fall was removed by brushing from both areas also in 1914 and 1915.
Number of living plants on July 23rd, 1916.	4	6	
Number of living plants in June 1918.	0	4	
Average height of surviving plants in June 1918, in inches	0	10 (8.5 to 13)	

27. The chief points of interest in this experiment are :

- (1) Except in Sub-Plot (3) where the soil was hoed around the plants, removing the overhead cover above 3-years-old seedlings raised in the shade has resulted in the death of all the plants in a period of 2 years. In Sub-Plot (3) it has resulted in the death of 86 per cent of the existing seedlings, 79 per cent of the plants dying within 3 months after the felling.
- (2) With reference to the above result it must be remembered that 1916 was an unusually dry season, and also that opening the cover in the cold weather would probably have given rather better results than in this case where the cover was removed in May. By opening in the cold season the surface soil would have obtained a considerable supply of moisture from the heavy dews which would probably have helped the plants to withstand the hot season in April-June. On the other hand, it must be remembered that the number of plants on the ground at the beginning of the experiment represent what is likely to be obtained only after a full seed year and after an unusually favourable season for germination and early growth, as was the year 1913 when the areas were sown. Also, the loosening of the surface soil by hoeing in Sub-Plot (3) is likely to have considerably mitigated the injurious effect of the late removal of the cover in May. On the whole, therefore, it is believed that the results in Sub-Plot (3) fairly represent what is likely to be obtained from this system on a large scale in the forest, without hoeing the soil.
- (3) The results obtained in Sub-Plot (3) show that under this system of working we may expect an average height-growth of 10 inches after 5 years, with less than 2 per cent. of surviving plants calculated on the number of seeds sown. If it is proposed to incur the considerable extra expense necessitated by hoeing the soil, in order to increase the number of survivors, it is obviously advisable to make sure of a large percentage of survivors by supplementing the work with artificial sowing. Thus, by sowing directly on dug soil in the open, as in Plot IV (see paras. 22 and 23 (6) above), we could get in one year the same height-growth as would be produced under the other system in 5 years and with more than 60 per cent. of surviving plants.

- (4) After the removal of the cover in May 1916, the Sub-Plots, in this case, were not weeded. The weed growth was scanty in 1916 but increased in 1917, and in June 1918 the surviving plants were being suppressed and weeding had become essential.

Thus this system does not eliminate the necessity for weeding, unless the plants are considerably older than 3 years before removing the cover.

Conclusions.

28. Removing the overhead cover in patches 60 feet in diameter from above 3-years-old seedlings raised in the shade results in a high percentage of deaths (79 per cent. of the existing seedlings) and weeding becomes necessary two years after the felling to prevent the suppression of the surviving plants. This indicates that seedlings raised in the shade should not be freed from overhead cover until they are considerably older than 3 years.

EXPERIMENT NO. V.

Object to test the advantages of regenerating in the open, in average and not particularly favourable seasons, to test the effect of clearings of different sizes and to obtain information regarding the extent and kind of weeding necessary.

29. As the remarkably good results in the way of seedling growth in the open in Plot IV reported in Experiment III above and in Plots VIII and III reported in *Ind. For. Rec.* V, 4, Part II, p. 61 (1916) had been obtained in an unusually favourable season, i.e. 1913, it was obviously desirable :

- (1) to repeat the experiment on a larger scale to see if similar results could be got in a less favourable season.
- (2) To obtain some information regarding the advantages of clearing areas of different sizes.
- (3) To obtain some information regarding the extent and kind of weeding which is necessary before *sal* seedlings can be thoroughly established in the open.

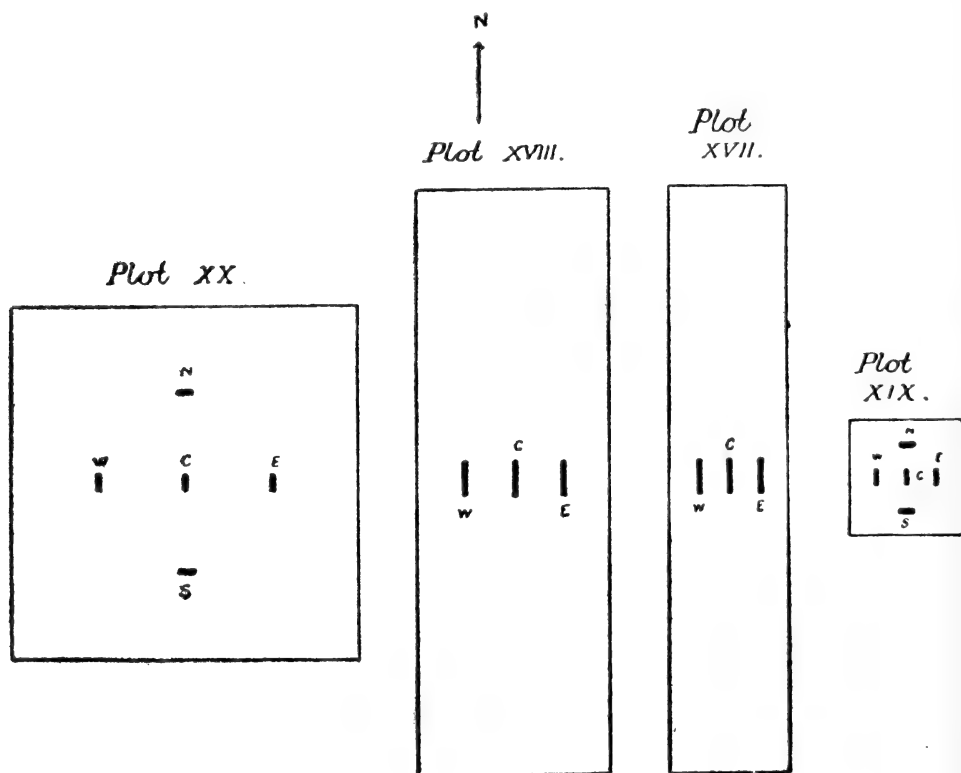
These were the objects of the present experiment.

30. The areas utilized in this experiment were the following, all situated in the Lachiwala forest near Plots IV, V and VI :—

- (1) *Plot XVII.*—A strip 300 feet long and 60 feet wide, running due north and south.
- (2) *Plot XVIII.*—A strip 300 feet long and 100 feet wide, running due north and south.
- (3) *Plot XIX.*—A square, the side of the square being 60 feet long.

(4) *Plot XX*.—A square, the side of the square being 180 feet long.

The average height of the forest in the neighbourhood of these areas was approximately 80 feet (from 60 feet to 100 feet). Thus the width of the strip in area (1) and the side of the square in area (3) was $\frac{3}{4}$ the average height of the surrounding trees, whereas in area (4) the side of the square was more than twice the average height of the surrounding trees. Each of the four areas was surrounded by forest on all four sides. All the standing trees and shrubs on these four areas were felled in May-June 1915. In the centre of Plots XVII and XVIII 3 beds (each 18 feet \times 3 feet) for sowing were selected, one in the centre, one on the west and one on the east. In Plots XIX and XX, 5 beds (each 9 feet \times 3 feet) for sowing were selected, one in the centre, one on east, one on north, one on west and one on south. The general position of the beds is shown in the plan of each area given below:



All leaves and débris were first swept off the beds, the latter were then dug and the seed just buried in the surface soil on June 18th, 1915.

31. An abstract of the observations recorded is given below and also details of two areas similarly dug and sown at the same time in the shade of the local *sal* forest in Plots XI and XII :—

—	Date of sowing.	Area sown in feet.	Number of seeds sown.	Number of healthy plants at close of one year on July 28th, 1916.	Percentage of healthy plants on July 28th, 1916.	REMARKS.	
Plot XVII, cleared north-south strip 300 ft. x 60 ft.—	June 18th, 1915					Germination was good in all beds in Plots XVII, XVIII, XIX and XX. The differences asserted themselves chiefly in February-May 1916 when the majority of deaths took place. The majority of the deaths were almost certainly, therefore, due to drought.	
East . . .		18 x 3	400	176	458 } 38		
Centre . . .		18 x 3	400	125			
West . . .		18 x 3	400	157			
Plot XVIII, cleared north-south strip 300 ft. x 100 ft.—							
East . . .		18 x 3	400	132	440 } 37		
Centre . . .		18 x 3	400	186			
West . . .		18 x 3	400	122			
Plot XIX, cleared square with 60 ft. side—							
Centre . . .		9 x 3	200	52	389 } 39		average 35.
East . . .		9 x 3	200	99			
North . . .		9 x 3	200	88			
West . . .		9 x 3	200	69			
South . . .		9 x 3	200	81			
Plot XX, cleared square with 180 ft. side—							
Centre . . .		9 x 3	200	18	251 } 25		
East . . .		9 x 3	200	60			
North . . .		9 x 3	200	38			
West . . .		9 x 3	200	104			
South . . .		9 x 3	200	31			
Plot XI in shade, light intensity 0.08, humus removed three seasons, soil once dug.			18 x 3	400	30		8	average 5
Plot XII in shade, light intensity 0.06, humus removed three seasons, soil once dug.	June 20th, 1915	18 x 3	400	6	2		

Very little weed growth established itself on the open plots during the first rains, and very little weeding was done. By July 1916, however, the weed growth had increased, and it was then markedly heavier in the larger clearings, Plots XVIII and XX, than in the smaller clearings, Plots XVII and XIX. As an illustration of the relative weed growth in Plots XIX and XX, see Plate V. Beginning with July 1916, therefore, in order to test the effect of weeding, one half of each bed in Plots XIX and

XVIII was kept weeded and the other half left unweeded, the observations on the seedling growth being continued. The weeding was done twice annually, once at the beginning and once at the end of the rains. The additional observations regarding the further development of the seedlings in the weeded and unweeded halves of the beds in Plots XVIII and XIX are given below :

—	Date of sowing.	Area sown in feet.	Number of seeds sown.	Number of healthy plants at end of 3½ years in January 1919.	Percentage of healthy plants in January 1919.	Average height in inches of plants in January 1919, when 3½ years old.	REMARKS.
Plot XVIII, strip 300' x 100'. Weeded—	June 18th 1915						
East . . .		9 x 3	200	38	22	19.8	For the average height, the 3 best plants were measured in the plots of 27 square feet and the 2 best plants in each of the others.
Centre . . .		9 x 3	200	59		33.2	
West . . .		9 x 3	200	37		27.3	
				134		average 26.8	
Plot XVIII, strip 300' x 100'. Unweeded—							
East . . .		9 x 3	200	25	15	34.4	
Centre . . .		9 x 3	200	41		40.3	
West . . .		9 x 3	200	24		32.3	
				90		average 35.7	
Plot XIX, square 60' x 60'. Weeded—							
Centre . . .		4½ x 3	100	29	37	32.8	average 29.3
East . . .		4½ x 3	100	37		32.6	
North . . .		4½ x 3	100	37		29.9	
West . . .		4½ x 3	100	47		25.2	
South . . .		4½ x 3	100	35		25.8	
				185			
Plot XIX, square 60' x 60'. Unweeded—							
Centre . . .		4½ x 3	100	23	23	30.3	average 30.1
East . . .		4½ x 3	100	17		32.8	
North . . .		4½ x 3	100	20		34	
West . . .		4½ x 3	100	27		30.4	
South . . .		4½ x 3	100	30		23.1	
				117			

32. The chief points of interest in this experiment are :

- (1) In a comparatively unfavourable season, with the normal heavy rainfall of 75 inches for the period June to September followed by an unusually dry hot weather, the results, as regards the number of surviving plants at the end of the year, are approximately 7 times better in the cleared areas, plots XVII-XX, than in the shade plots XI and XII.
- (2) No damage by frost was noticed in any of the cleared areas, plots XVII-XX.
- (3) Taking all the weeded and unweeded areas together of Plots XVIII (100' strip) and XIX (60' square), the average annual height-growth, calculated for the 3½ years period, is 8.7

inches which would give established seedlings approximately $3\frac{1}{2}$ feet high in 5 years.

- (4) Owing to the level of the ground falling towards the south of Plot XIX (60' square), a good deal of sunlight penetrated between the crowns of the trees and the side-shade from the south was not so heavy as was the case in Plot IV, the results for which have been reported in para. 23 (2) above. It will be noticed, however, that the height-growth in the southern bed of Plot XIX is distinctly inferior to that in the northern bed of the same Plot, both in the weeded and unweeded portions, which indicates the injurious effect of side-shade from the south. The southern bed of Plot XX (180' square) also received a good deal of side-shade from the south, during the autumn, winter and spring, but this appeared to be in no way beneficial in helping the plants to resist damage from drought, there being a larger number of casualties in this bed in May-June 1916 than in the northern bed of the same Plot which received practically no side-shade at all.
- (5) Other beds which also gave decidedly inferior results were the northern and central beds of the 180 feet square. These areas received practically no side-shade at all, from the east, south or west. A large number of plants died from drought here in the dry season February to June 1916.
- (6) The areas which received a considerable amount of side-shade, both in the morning from the east and in the afternoon from the west, gave uniformly good results, with 39 per cent. survivals at the end of the first year for all beds in Plot XIX (60 feet square), and 38 per cent. survivals for all beds in Plot XVII (60 feet wide, north-south strip).
- (7) As the width of the north-south strip increases and exceeds the average height of the trees, the results get slightly worse ; compare the rather inferior results as regards survivals at the end of the first year in the eastern and western beds of Plot XVIII (100 feet wide strip) with the results in the eastern and western beds of Plot XVII (60 feet wide strip). Also compare the height-growth at the end of $3\frac{1}{2}$ years in the weeded eastern and western beds of Plot XVIII with the height-growth in the weeded central bed of the same Plot. This inferior result is probably due to a rather longer exposure of the western portion of the strip to the morning sun and of the eastern portion to the afternoon sun.

- (8) The western bed in Plot XX (180 feet square) gave by far the best results of all the beds in this plot, thus indicating that when side-shade is received chiefly from one direction only, side-shade from the west and shelter from the hot afternoon sun appears to be the best.
- (9) Owing to the scanty weed growth, weeding was unnecessary in the small 60 feet square after the first rains, there being 23 per cent. living seedlings with a height-growth of 30 inches in the unweeded areas after $3\frac{1}{2}$ years.
- (10) In the case of the larger clearings, *viz.*, the 100 feet wide strip, the weed growth was much heavier, but here there is no doubt that the weeding was over-done, as the height-growth is obviously poor in the weeded areas and the plants look less healthy with yellower leaves. In the case of a large clearing like this, some extra light lateral shade, such as that given by isolated plants of the large tufted grasses *Saccharum Munja*, *S. Narenga* and *Erianthus Ravenanæ*, or a few woody coppice shoots, appears to be decidedly beneficial both in decreasing water loss from the seedlings and in preventing the development of a matted growth of herbaceous plants, like *Ageratum*, *Desmodium*, small grasses and others, which rapidly swamp and kill young *sal* seedlings, see Plate VI, fig. 2.

Plate VI, Fig. 1, shows the $3\frac{1}{2}$ years-old seedlings in the weeded and unweeded portions of the centre bed in Plot XVIII (100 ft. wide strip). Note the plants of exceptional vigour which have established themselves among the coarse grasses in the unweeded area.

Summary of conclusions.

33. On the whole, the following conclusions seem to be justified by this experiment :

- (1) In a comparatively unfavourable season and on a comparatively large scale, the seedling growth obtained in the cleared patches and strips has been only slightly inferior to that obtained in the favourable year 1913 in Plot IV, and is 7 times better than that obtained by sowing in the shade.

The average annual height-growth, calculated for the $3\frac{1}{2}$ years period, is 8.7 inches which would give established seedlings $3\frac{1}{2}$ feet high in 5 years, see para. 32 (1) (3).

- (2) In the clearings, the best and most uniform results are obtained in patches the diameter of which is $\frac{3}{4}$ ths the average height of the surrounding trees, and on strips running north and south the width of which is $\frac{3}{4}$ ths the average height of the surrounding trees. In such clearings frost does no damage. If the diameter of the patches and the width of the strips is increased much beyond this limit, weed growth becomes more troublesome and the seedlings suffer from drought, *see* para. 32 (2) (5) (6) (7) (9) (10) and p. 44.
- (3) Side-shade from the south is injurious, whereas side-shade from the east and west is beneficial and, therefore, the results on narrow north-south strips are uniformly good. On the other hand, east-west strips would give the maximum side-shade from the south, and it is, therefore, probable that the results on such strips would be decidedly inferior, *see* para. 32 (4) (6).
- (4) In cases where side-shade is received mainly from one direction only, that from the west which affords protection from the hot afternoon sun is most beneficial, *see* para. 32 (8). This indicates that it may be possible to regenerate these forests by progressive strip fellings passing from the east through the forest towards the west. Whether this can be done however, without causing excessive weed growth or subsequent damage to the young growth by frost or drought cannot be decided until further experiments have been carried out.
- (5) In the smallest clearing, *viz.* the 60 feet square, very little weed appeared during the first rains, and after this weeding was unnecessary, *see* para. 32 (9).
- (6) In the larger clearings, *e.g.* the 100 feet wide strip, one weeding at the end of the first rains, one at the beginning and end of the next rains, and one during the next year would probably be quite sufficient, *i.e.* 4 in all.

Weeding should be done with discrimination and scattered plants of the large tufted grasses or a few woody coppice shoots (which can be topped when necessary) are often beneficial in decreasing water-loss from the plants, and in preventing the development of the highly injurious matted growth of herbaceous weeds, *see* para. 32 (10).

- (7) In order to diminish trouble from weed-growth, it is desirable to regenerate small cleared patches first, and then to gradually extend these areas in the form of narrow north-south strips.

EXPERIMENT No. VI.

Object to test effect of broadcast sowing on dug and undug soil and on a layer of leaves.

34. In the previous experiments the seed-beds had invariably been dug, and the seed had been just buried in the surface soil. The object of the present experiment was to determine the results likely to be obtained when the seed was merely scattered on the surface, broadcast, without being buried and when the soil was not dug before sowing; also to test the effect of a layer of dead leaves on germination and early growth under forest conditions.

35. The areas utilized were :

- (1) Plot XVII, the strip 300 feet \times 60 feet clear-felled in 1915, which was mentioned in the last experiment. The soil, therefore, had been exposed to the sun for a year before this experiment commenced and was, therefore, somewhat hardened. The area dealt with was situated in the middle of the strip, immediately adjacent to the plots mentioned in the last experiment and inside the fenced area. Grass and existing weeds were cut on June 12th, 1916, but the area was not dug.
- (2) Plot XXI, a new plot selected in the shady forest immediately adjacent to Plot XVII. The surface covering of humus was swept off and seedlings and small weed-growth were removed on June 11th, 1916.

Each of these plots was divided into 3 sub-plots which were treated as follows :—

Sub-plot I.—A layer of dead *sal* leaves, 6 leaves thick, was laid on the surface, and the seed was sown broadcast on the dead leaves.

Sub-plot II.—A layer of dead *sal* leaves, 6 leaves thick, was laid on the surface and then burnt off, the seed then being sown broadcast on the soil surface.

Sub-plot III.—A layer of dead *sal* leaves, 6 leaves thick, was laid on the surface and then burnt off. The soil was then dug and the seed was sown broadcast on the dug soil.

The area of each sub-plot was 18 feet \times 6 feet. The burning and digging was done on June 13th, 1916.

36. An abstract of the observations recorded is given below :—

Plot and Sub-plot.	PLOT XXI UNDER SHADE OF FOREST.			PLOT XVII CLEARED STRIP 300 FEET×60 FEET.		
	I	II	III	I	II	III
	18' × 6'	18' × 6'	18' × 6'	18' × 6'	18' × 6'	18' × 6'
	Seed on dead leaves.	Seed on soil surface, soil not dug.	Seed on soil surface, soil dug.	Seed on dead leaves.	Seed on soil surface, soil not dug.	Seed on soil surface, soil dug.
Date of sowing	June 15th, 1916.					
Number of seeds sown	800	800	800	800	800	800
Percentage of healthy plants on March 31st, 1917.	0	0	0	6	24	25

Summary of conclusions.

37. From the above, the following conclusions seem justified :

- (1) The broadcast sowings in the open were very fairly successful, while those in the shade were a total failure.
- (2) The layer of dead leaves on the soil surface was decidedly injurious.
- (3) The results in the dug soil were not obviously better than those in the undug soil.

EXPERIMENT No. VII.

Object to test effect of broadcast sowing on a large scale without fencing of any kind.

38. When the present series of forest experiments was first started in 1912, porcupines did a lot of damage to the seeds in some of the plots ; as it was difficult to estimate at all exactly how many seeds had been destroyed, this interfered considerably with the experiments. After that year, therefore, all the experimental sowings were protected by wire netting of 1 inch mesh, placed 2 feet above the ground, buried 1 foot below the surface and fastened above to the barbed wire fence which surrounded the plots (*Ind. For. Rec.* V. 4, Part II, 1916, pp. 52,60).^{*} As fencing of this kind on a large scale in the forests would be prohibitive, it was obviously advisable to see if similar results to those

^{*} One remarkable fact about these fences is that injurious herbaceous weeds frequently establish themselves in dense masses inside the fenced areas. This is especially the case with *Ageratum*. Plate VI. Fig. 2, shows a fenced area where *sal* seedlings were entirely killed out by this weed which at present gives no trouble whatever in this locality in unfenced areas.

recorded in the above experiments could be obtained on a fairly large scale in the forests by sowing broadcast, without fencing of any kind, and under varying conditions of overhead light. This was the object of the present experiment.

39. The areas utilized were :

Plot XVII.—The cleared strip 300 feet long by 60 feet wide, running north and south, mentioned in experiment V above. The strip was cleared in 1915. In the present experiment the area utilized was that lying outside the central fenced area which contained the sowings of 1915 and 1916.

Plot XVIII.—The cleared strip 300 feet long by 100 feet wide, running north and south, mentioned in experiment V above. The strip was cleared in 1915. In the present experiment, the area utilized was that lying outside the central fenced area which contained the sowings of 1915.

Plot XXV.—A strip 210 feet long by 60 feet wide, running north and south, in the forest immediately adjacent to Plot XVII. The overhead cover was left intact, but all the undergrowth, shrubs and small trees forming the second storey were cleared in May 1917, thus lessening the shade considerably, a general view of this plot, from the south, is seen in Plate VII, Fig. 1 which gives an idea of the number of trees left on the area.

Plot XXVI.—A strip 210 feet long by 60 feet wide, in the forest immediately adjacent to Plot XVII, running north and south, and precisely similar to Plot XXV except that, in this case, in addition to removing all the undergrowth, the main overhead cover was broken by thinning out the large trees, an average space of about the diameter of one crown being left between the crowns. A general view of this plot from the south is seen in Plate VII, Fig. 2.

The trees and shrubs were cut in Plots XXV and XXVI from May 11th to 27th, 1917, and at the same time the dead leaves and débris on the soil were swept off. As the strips XVII and XVIII had been cleared in 1915, a fairly heavy weed growth had established itself, especially in Plot XVIII, before the present experiment was started. All such weed growth was cut and left to lie on the ground for a month before this experiment commenced, in order to weaken the growth as far as possible. The cut growth was then removed by hand in the first week of June 1917. Each plot was divided into 4 sub-plots, by lines running east to west across the area, which were numbered I-IV commencing from the north. Each sub-plot was again sub-divided into 3 equal parts, by lines running east to west across the area, which were designated

a-c, commencing from the north. The treatment of all the areas was precisely the same, *viz.* :—

Area (*a*). A layer of dead *sal* leaves, 6 leaves thick, was laid on the surface and the seed sown broadcast on the dead leaves.

Area (*b*). A layer of dead *sal* leaves, 6 leaves thick, was laid on the surface and then burnt off, the seed then being sown broadcast on the soil surface.

Area (*c*). A layer of dead *sal* leaves, 6 leaves thick, was laid on the surface and then burnt off. The soil was then dug and the seed sown broadcast on the dug soil.

In Plots XVII, XXV and XXVI, each separate area (*a*) (*b*) and (*c*), respectively, measured 20 feet from east to west \times 15 feet from north to south. In Plot XVIII, each separate area (*a*), (*b*) and (*c*), respectively, measured 40 feet from east to west and 15 feet from north to south. The digging in all cases consisted merely of rough hoeing with a *pharwa*, similar to the work carried out in tea-gardens. All natural seed falling on the areas was removed before sowing commenced, as well as all existing seedlings.

The leaf-fall of 1918 was brushed off in June 1918, and the natural seed falling on the areas in June-July 1918 was also removed. The areas were weeded in October 1917, June 1918 and at the end of August 1918. In sub-plot IV of all the plots, which received heavy shade from the south, the results were uniformly bad, thus indicating that, in a year of heavy rainfall, side-shade from the south is decidedly injurious. In the period June-September 1917 the rainfall was 102 inches as compared with the normal 75 inches.

40. An abstract of the observations recorded in the remaining sub-plots is given below :

Plot.	PLOT XXV. UNDERGROWTH REMOVED, OVERHEAD COVER MAINTAINED INTACT.						PLOT XXVI. UNDERGROWTH REMOVED AND OVERHEAD COVER BROKEN, A SPACE ONE CROWN IN DIAMETER BEING LEFT BETWEEN THE CROWNS.						REMARKS.			
	Seed on layer of dead leaves.			Seed on soil sur- face, soil not dug.			Seed on layer of dead leaves.			Seed on soil sur- face, soil not dug.						
	Sub-plot.			Sub-plot.			Sub-plot.			Sub-plot.						
Area in square feet	I (a)	II (a)	III (a)	I (b)	II (b)	III (c)	I (a)	II (a)	III (a)	I (b)	II (b)	III (c)	I (c)	II (c)	III (c)	
Date of sowing	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	Seeds were sown through- out at the rate of 6 seeds per square foot of area. The percentages of living plants are in all cases calculated on the number of seeds sown. The average height was obtained in each plot by marking out an area of 150 square feet (10 feet x 15 feet) showing the best growth and then measur- ing the 15 best plants in the area, at the rate of 1 plant per 10 square feet. In the following cases, as 15 plants could not be found in the area only the numbers noted below were measured:— (a) one plant measured, (b) three plants measured, (c) eleven plants measur- ed, (d) six plants measured, (e) one plant measured, (f) nine plants measured, (g) one plant measured, (h) two plants measured, (i) four plants measured, (m) five plants measured, (n) one plant measured, (o) three plants measured.
Percentage of living plants in January 1919, i.e. when 1½ years old.	0.3	0	0	0.3	0.5	0.3	1.1	1.1	0.5	7.1	8.4	10.1	14.7	7.6	14.2	
Average height of healthy plants in inches in January 1919, when 1½ years old.	(a) 4.25	0	0	(b) 4.4	(d) 3.5	(e) 4.0	(f) 4.3	(f) 5.7	(g) 6.25	5.4	5.1	7.3	7.4	6.7	6.9	
Plot.	PLOT XXVII. CLEARED STRIP 300 FEET X 60 FEET.						PLOT XXVIII. CLEARED STRIP 300 FEET X 100 FEET.									
Area in square feet	Seed on layer of dead leaves.			Seed on soil sur- face, soil not dug.			Seed on layer of dead leaves.			Seed on soil sur- face, soil not dug.						
Date of sowing	Sub-plot.			Sub-plot.			Sub-plot.			Sub-plot.						
Percentage of living plants in January 1919, i.e. when 1½ years old.	I (a)	II (a)	III (a)	I (b)	II (b)	III (c)	I (a)	II (a)	III (a)	I (b)	II (b)	III (c)	I (c)	II (c)	III (c)	
Average height of healthy plants in inches in January 1919, when 1½ years old.	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	
	0.2	0.6	0.9	7.9	13.9	13.4	1.2	1.7	0.7	7.7	3.5	2.4	10.6	6.9	9.5	
	(h)	(i)	(l)	8.0	11.0	9.2	(m)	(n)	(o)	11.4	9.3	8.5	13.1	9.9	14.8	
	5.3	6.0	4.8	9.4	11.8	12.0	7.7	8.0	6.5	9.7	9.7	8.5	12.6	12.6	14.8	

Plate VIII, Fig. 1, shows the $1\frac{1}{2}$ -years-old seedlings in Plot XVIII, 1 (c), on 31st January, 1919, and Fig. 2 of the same Plate shows the $1\frac{1}{2}$ -years-old seedlings in Plot XVII, II (c), on the same date.

41. The chief points of interest are :—

- (1) The results in this experiment have been obtained on a fairly large scale, under forest conditions, by sowing broadcast and with no fencing of any kind.
- (2) The sowings on dead leaves throughout, both under shade and in the open, have proved a failure, the survivals in all cases being less than 2 per cent.
- (3) In every plot, both in the shade and in the open, the results on the dug soil have been distinctly better than on the undug soil, both as regards the number of survivals and the height-growth. In some cases, where the ground is fairly level and the soil surface has not been hardened, quite good results may be seen on the undug soil. When the ground, however, is not level, the seed is quickly washed off by the rain, whereas, in dug soil, the rainfall percolates *in situ*, the seeds are not washed away, a well-distributed and even stocking results and an equable distribution of moisture in the soil is secured.
- (4) In the area with the heaviest shade, *viz.* Plot XXV, the sowings have been practically a failure with less than 3 per cent. survivals on the dug soil. This indicates that clearing the undergrowth without interrupting the overhead cover is of little use,
- (5) In Plot XVII where the overhead cover has been completely removed on a strip 60 feet wide, the results are undoubtedly much the best with 25 per cent. survivors and a height-growth of 12 inches after $1\frac{1}{2}$ years.

In considering this result, also, it must be remembered that, when this experiment started, the strip had been cleared for 2 years, and a good deal of weed growth had already established itself.

- (6) The rather poor results in Plot XVIII, the cleared strip 100 feet wide, are due to the bad growth in sub-plot IIc. In this area a dense matted growth of grass (*Eragrostis cynosuroides* and *Imperata arundinacea*) had established itself which impeded germination and interfered with seedling development. This was due to the fact that the line had been cleared and exposed to full light for 2 years before the experiment started, it having been cleared first in 1915. With ordinary care, full regeneration can be secured in the

first year after the clearing or, at latest, in the second year, and dense weed growth of this kind should not be encountered. Omitting the results for sub-plot IIc, we get the following results in Plot XVIII after $1\frac{1}{2}$ years :

percentage living plants = 10

average height growth = 14 inches.

This is distinctly better than Plot XXVI, in which the overhead cover was not completely removed, with 12 per cent. survivals and a height-growth of only 7 inches.

- (7) In Plot XXVI, in which the overhead cover had been only partially removed, the seedling growth was distinctly patchy, and was invariably best where there was least overhead cover or where the ground was most exposed to the sun from the south. In June 1917, also, when the sowings were carried out, the trees had been badly defoliated by caterpillars, and the results in the plot, as a whole, are probably considerably better than would be obtained under ordinary circumstances. The usual advantages quoted for the system of leaving partial cover as compared with that of complete clearing are :

- (a) More seed reaches the ground from the trees standing on the area,
- (b) Weed growth is less.

As regards (a), *sal* seed is carried quite a considerable distance by the wind ; in 1916, the writer collected in these forests 34 seeds from an area 18 feet \times 3 feet, the nearest trees to the edge of the area being at a distance of $48\frac{1}{2}$ feet, and 7 seeds from an area of 27 square feet situated 87 feet from the nearest trees. A considerable quantity of seed, therefore, can find its way on to a cleared strip 60 feet wide, and even if a greater quantity does fall on the partially cleared area, this is discounted by the larger proportion of seed which fails to germinate and of seedlings which fail to survive under the cover of the trees. Moreover, owing to the uncertainty of good seed years, no really satisfactory system of regeneration can rely entirely on natural seed. With reference to (b), while in a given time less weed does no doubt establish itself where shade trees are left than where the cover is entirely removed, this is more than counter-balanced by the following considerations :

- (1) The weed growth is strongest where the seedlings chiefly survive, *i.e.* where there is least shade.

- (2) Owing to the less vigorous and slower growth of the seedlings, the weeding must be continued longer.
- (3) A considerable proportion of the area is not stocked with seedlings.
- (4) When the standing trees are eventually felled, the young growth is liable to be damaged.

Summary of conclusions.

42. The following conclusions appear to be justified by this experiment :
 - (1) A layer of dead leaves on the ground is very injurious to germination and seedling development, *see* para. 41 (2).
 - (2) In order to get good results uniformly and quickly, hoeing is necessary, *see* para. 41 (3).
 - (3) Sowings with the overhead cover intact result practically in failure, *see* paragraph 41 (4).
 - (4) Sowing after interrupting the overhead cover gives results much inferior to those obtained by sowing on a cleared strip 60 feet wide, *see* para. 41 (5) (7).
 - (5) Broadcast sowings under forest conditions, on hoed soil, without fencing of any kind, with one weeding in the first year and two in the second year, on a cleared north-south strip 60 feet wide (this width being about $\frac{3}{4}$ the average height of the surrounding trees), have given 25 per cent. surviving seedlings after $1\frac{1}{2}$ years, with an average annual height-growth of 8 inches. This would give established seedlings approximately $3\frac{1}{2}$ feet high in 5 years, *see* para. 40.
 - (6) Similar sowings on a cleared north-south strip 100 feet wide (this width being about $1\frac{1}{4}$ the average height of the surrounding trees) have given 10 per cent. surviving seedlings after $1\frac{1}{2}$ years with an average annual height-growth of 9 inches. This would also give established seedlings approximately $3\frac{1}{2}$ feet high in 5 years, *see* para. 41 (6).
 - (7) Side-shade from the south in a year of heavy rainfall is decidedly injurious to the development of *sal* seedlings, *see* para. 39.

EXPERIMENT NO. VIII.

Object to determine the effect of sowing in the open in a season unfavourable for germination.

43. The experiment recorded below is interesting, since it indicates the results likely to be obtained by broadcast sowings in a cleared patch in a season unfavourable for germination and early growth, with an unusually short rainfall at the end of June and in July.

44. The areas utilized were :—

- (1) Plot VI, where a patch 60 feet in diameter was cleared in May 1916, all standing trees and shrubs having been removed, see para. 26 above. In the present experiment, the area utilized was that lying outside the central fenced area which contained the beds dealt with in experiment No. IV above. From June 7th-9th, 1918, all dead leaves lying on the area were swept off, coppice shoots were cut, weeds removed by hand, the area demarcated and one half of it dug, the remainder being left undug. On June 21st, 1918, seed was sown broadcast throughout the area at the rate of 6 seeds per square foot.
- (2) Plot XXI in the shade of the adjacent forest. In the present experiment the area utilized was that lying outside the central fenced area which contained the beds dealt with in experiment No. VI above (see para. 35). In May 1917, all trees and shrubs standing on the plot which were less than 12 inches in girth were felled. The overhead cover was thus left intact but the shade was lessened considerably by the removal of all the small trees and shrubs forming the second storey in the forest.

From June 10th-12th, 1918, all the dead leaves and débris lying on the area were swept off, weeds were removed by hand, the area demarcated and one-half of it dug, the remainder being left undug. On June 21st, 1918, seed was sown broadcast throughout the entire area at the rate of 6 seeds per square foot.

45. The following is an abstract of the observations :

Plot.	PLOT XXI.		PLOT VI.		REMARKS.
	IN SHADE OF FOREST. UNDERGROWTH REMOVED OVERHEAD COVER IN- TACT.		IN THE OPEN, IN A CLEARED PATCH 60 FEET IN DIAMETER.		
	I	II	I	II	
	Area 600 square feet. 20 feet x 30 feet. Soil dug.	Area 600 square feet. 20 feet x 30 feet. Soil not dug.	Area 600 square feet. 20 feet x 30 feet. Soil dug.	Area 600 square feet. 20 feet x 30 feet. Soil not dug.	
Date of Sowing	June 21st 1918.				Percentages are calculated on the number of seeds sown.
Number of seeds sown broad- cast on the surface.	3,600	3,600	3,600	3,600	
Number of healthy plants in January 1919.	28	1	444	104	
Percentage of healthy plants in January 1919.	0·8	0·03	12·3	2·9	

46. The chief points of interest are :—

- (1) In a year unfavourable to germination and early growth with a short rainfall at the end of June and in July, sowings in a cleared patch 60 feet in diameter have been much more successful than those carried out in the forest under shade. It is believed that this is due to more moisture being available in the cleared patch which gets the full benefit of dew and very light showers which do not reach the soil in the shady forest. At the same time, the evaporation of moisture from the soil of the patch is retarded by the heavy side shade.
- (2) Both in the shade and in the open, the results in the hoed soil were much better than those in undug soil.
- (3) The hoed areas in Plot VI were very fairly stocked with seedlings well distributed throughout the area, although the percentage of survivals was poor, *viz.* only 12 per cent. This shows the great advantage of sowing thickly which will secure a fairly full stock of seedlings even in unfavourable years.

Summary of conclusions.

47. The following conclusions appear to be justified :—

- (1) In an unfavourable year, with a short rainfall at the end of June and in July, sowings in cleared patches 60 feet in diameter are more successful than those in the forest under shade.
- (2) Broadcast sowings on hoed soil are more successful than those on undug soil.
- (3) Sowings should be done thickly, *e.g.* at a rate of 6 seeds per square foot of area, which will give a full stock of seedlings even in an unfavourable season.

CHAPTER III.

System of Regeneration proposed.

48. The question to be considered now is the extent to which the results of the experimental work reported above can be incorporated in a practical system of silvicultural management. As regards this question the results of greatest importance appear to be the following :—

- (a) the development of *sal* seedlings in the shade of the forest is very slow and unsatisfactory. This is due primarily to two factors, bad soil-aeration and drought. The latter is responsible for widespread damage during the season of short rainfall from September to June. Bad soil-aeration, on

the other hand, is responsible for heavy casualties during the rains, especially in the months July and August, and also causes a superficial, poorly developed root system which increases the subsequent damage by drought.

- (b) The conditions of soil-aeration and soil moisture can be greatly improved and the development of the seedlings can be much accelerated by making suitable clearings and by raising the seedlings in these open areas, instead of under the shade of the forest. In such clearings, the soil-aeration and root growth during the rains is improved by the partial drying out of the soil during the intervals of hot sunshine, while the soil moisture is increased and damage by drought diminished, during the cold and dry seasons, by heavy dew and light showers which fail to reach the soil under the heavy shade of trees.
- (c) To get satisfactory results in the local forests, the clearings should be so arranged that the seedlings obtain the full benefit of overhead light, together with side shade in the morning from the east and side shade in the afternoon from the west. Side shade from the south is injurious as it keeps the soil perpetually moist. Shade from the south side of the clearings, therefore, should be diminished. In order to diminish weed growth, the clearings should be small at first and should be gradually extended as the seedlings become established. The best results, therefore, are attained in small patches which are subsequently extended in the form of narrow strips running from north to south, the diameter of the patches and width of the strips being $\frac{3}{4}$ ths. the height of the adjoining trees. In such clearings, even in a frosty locality, frost does no damage to the seedlings.

49. It is believed, therefore, that the results which have been obtained indicate a modified combination of the group and strip systems to be the best method of securing the rapid regeneration of the type of *sal* forest here dealt with. As a general rule, it is at present accepted that it is unsafe to entirely remove overhead cover above *sal* seedlings unless the latter are thoroughly established and about $3\frac{1}{2}$ feet in height. From the observations and experiments reported above, it is estimated that a full stock of seedlings of this height cannot be obtained in the shade in less than 48 years, see para. 23 (9) (10) above.

Thus, if the forests are regenerated under shade in accordance with existing ideas, the process cannot be effected in less than 50 years. On the other hand, it is believed that the experiments which have been

reported above justify the conclusion that, under the system of artificial sowings in narrow cleared patches and strips, a complete stock of established seedlings $3\frac{1}{2}$ feet high could be obtained, under favourable conditions of labour and seed supply, in 5 years, see paras. 32 (3), 42 (5) (6) above.

As a suitable organization of labour to deal with large areas, however, will require time, it is proposed at first to reduce the area to be dealt with annually and to extend the regeneration period to 15 years, this being divided into 3 sub-periods each of 5 years.

Under the system advocated in this paper, therefore, it is believed that the regeneration period could be shortened by not less than 35 years.

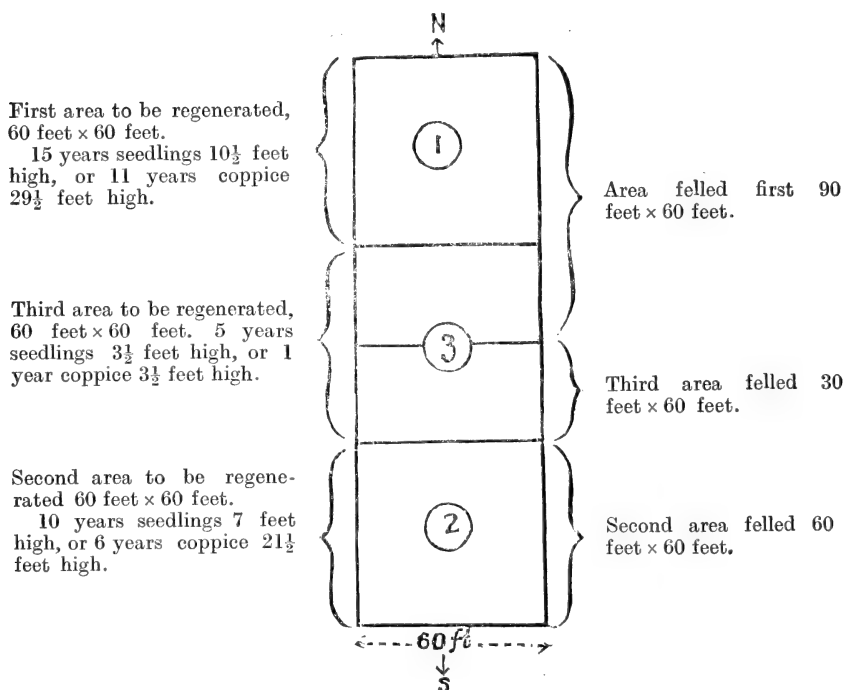
Details of System of Regeneration proposed.

50. The system of regeneration proposed is really a modified combination of the Group and Strip systems. Its main features are indicated by the following prescriptions:

- (a) Assuming the rotation to be 150 years, determine the average height of the forest at an age of 75 years.
- (b) Divide the area permanently into narrow strips running due north and south, the width of the strips to be $\frac{3}{4}$ ths of the average height of the forest at the age of 75 years. Thus, assuming the average height to be 80 feet, the width of the strips would be 60 feet.
- (c) Only the alternate strips are to be regenerated first, *i.e.* the regeneration area = $\frac{1}{2}$ the total area. The remaining strips are not to be regenerated until the young growth on the regenerated strips has attained the height of 80 feet, *i.e.* when it is 75 years old.
- (d) The regeneration period to be 15 years, divided into three sub-periods of 5 years each.
- (e) Each strip of the regeneration area to be divided into segments, the length of each segment to be 3 times the width of the strip, *i.e.* in this case 180 feet, and each segment to contain 3 unit areas, each 60 feet \times 60 feet. The first unit will be regenerated in the first sub-period of 5 years, the second in the second sub-period, and the third in the third and last sub-period. An interval of 4 years to elapse between the felling of any two units in the same segment. In this way the rapid clearing of large areas and the establishment of a strong growth of weeds will be prevented.
- (f) In the area to be regenerated during each sub-period of 5 years, those units, already fully stocked with advance

growth which merely requires cutting back, should be felled in the last 1-2 years of the sub-period. This will tend to make the young crop uniform and will also prevent excessive shade on the south of unit (2) from high coppice growth in unit (1) to the south of it. No attempt, however, should be made during the first rotation to introduce rigid uniformity in the crop at an unreasonable financial sacrifice, and promising pole woods should be left to form a part of the future crop.

- (g) The area to be felled and regenerated, respectively, in a sample segment is indicated below, together with the age and approximate height of the young growth at the end of the regeneration period of 15 years, in a segment which has been successfully regenerated.



It will be noticed that, south of unit (1), an area 60' \times 30' is felled in addition to the unit area itself, in order to diminish the shade on the south.

- (h) During the first rotation, owing to the large quantity of advance growth of varying ages in the forest most of which, if cut back, will produce vigorous shoots suitable for retention in the new crop, there must be considerable irregularity in the new crop, the coppice growth being naturally far more vigorous, at all events at first, than the young seedling growth. In the second rotation, there will probably be much less old advance growth and the young crop will be more uniform.
- (i) The regeneration period should be considered to commence from the time of the first sowing.
- (j) In the areas to be regenerated, felling should be done as early as possible in the cold season, so that the soil may be well moistened by dew and light showers. All dead leaves and debris to be burnt and the soil hoed in April-May following.
- (k) As a rule, a large quantity of natural seed will reach the regeneration areas, but this cannot be depended on and seed should be sown broadcast at the rate of not less than 6 seeds per square foot of area, to secure a fairly full stock of seedlings even in unfavourable seasons. Sowing should be deferred, if possible, until the rains have set in, and care must be taken to see that the seed is healthy and in good condition. Covering the seed with soil materially increases the percentage of germination.

Advisability of applying the system proposed to selected areas as an experimental measure.

51. In the system which has been sketched above, it will be noticed that the fellings are scattered through the forest which is obviously less convenient than if they were concentrated in one part of the forest. At the same time they are situated on definite strips and are more concentrated than in the Selection, Compartment, or Group systems. On the other hand, the small scattered felling areas are advantageous in hindering the establishment of a strong growth of weeds, and probably also in decreasing damage by insects. In the future, it may be found possible further to improve upon the system which is now suggested but, meanwhile, it is maintained that an effort ought now to be made to apply, in one or two selected areas, as an experimental measure, on a small scale, the system which has been sketched above, which has been shown to be safe and practicable by the experimental evidence which is now available and which offers a good

prospect of reducing the regeneration period by no less than 35 years. By putting this system into operation, also, in selected areas, a standard will be made available, by means of which it will be easy to determine the comparative value of improvements and modifications which may be subsequently suggested. It should be noted, also, that the suggested system is eminently suited for those forests which are composed chiefly of miscellaneous species, and in which it is desirable to increase the proportion of *sal*.

Possible Objections to the proposed System of Regeneration.

52. Before dealing with the possible objections which may be raised to the introduction of the system proposed, it must, in the first place, be clearly understood that this system is not intended to apply to :—

- (1) Semi-ruined areas, poorly stocked and with little or no undergrowth except a heavy growth of grass. Such areas are exceptional and require special treatment.
- (2) Forests where ample soil moisture is available by percolation or springs and where, owing to the sandy or gravelly nature of the soil, bad soil-aeration is not a factor of importance. In such localities, *sal* seedlings can be established successfully and fairly quickly under shade, and regeneration consequently presents no difficulty.
- (3) Forests exposed to particularly favourable climatic conditions where there is no fear of frost damage. In such cases, *sal* can be safely raised in the open on large clearings, *e.g.* in Assam and the Bengal Duars.

The principles of the system now proposed are intended to apply to the average fairly well-stocked *sal* forest on loam, in places where frost damage is to be feared, where the dying back of seedlings is a marked characteristic, and where the establishment of vigorous seedling growth is at present a slow and uncertain process.

53. In the second place, it must be borne in mind that the system proposed offers a good prospect of reducing the present regeneration period of these forests by not less than 35 years. If this result could be obtained cheaply and with very little trouble, it is fairly certain that it would have been realised long ago. Consequently, we must be prepared to encounter some difficulties and to incur such expenditure as is reasonable in view of the advantages to be obtained. With these preliminary remarks, the following possible objections to the proposed system will be shortly considered :—

- (a) *As most of the young growth now existing in the type of forest here dealt with appears to have originated under shade, the best and most natural method of securing regeneration must consist in encouraging the growth of seedlings under shade.*

The following considerations, it is believed, dispose of this objection :

- (1) most of the shade in the existing forests is the result of long fire-protection, and was not present when a considerable proportion of the young growth now in evidence first originated ;
 - (2) the Dehra Dun experiments have proved that the growth of *sal* seedlings in the shade is extremely slow, that a seedling requires not less than 40 years to develop a shoot 5 feet high in the shade, whereas in cleared patches or strips this height can be attained in 6-7 years. Our object, obviously, should be not to perpetuate a state of affairs under which the establishment of regeneration is extremely slow and unsatisfactory but to improve upon it as far as possible.
- (b) *The Dehra Dun experiments are on too small a scale to justify conclusions as to the suitability of the system on a large scale.*

In the first place, all other systems which have been tried on a similar small scale have invariably given inferior results to those yielded by the proposed system. In the second place, until we know enough about the different factors influencing growth to be able to explain correctly the results obtained, work on a large scale is apt to be misleading and to cause waste of time and money. To discover the effect of individual factors on growth much detailed observation work, involving the counting and accurate measuring of large numbers of seedlings, is essential and it is impossible to do this satisfactorily on a large scale. When results can be consistently obtained on a small scale, we only require a suitable organization of labour in order to obtain them on a large scale.

- (c) *If the strip system is best why does not sal regeneration establish itself in quantities on fire-lines ?*

In the first place many fire-lines are too wide, and others run in the wrong direction.

The Dehra Dun experiments have shown that, to get really good results, heavy sowing combined with hoeing the soil is necessary. On fire-lines the soil is not hoed and clearing the line may, or may not, be done in a good seed year.

Again, fire-lines are cleared throughout in a single operation and this encourages the rapid establishment of a heavy growth of weeds which swamps the few seedlings which may start growth during the first few years. After this the exposure, combined with annual burning, hardens the soil and renders it steadily less suitable for germination and early growth. The Dehra Dun experiments, however, have proved that, on a 100 feet wide north-east to south-west fire-line which has been cleared for 8 years, excellent seedling growth can be obtained if the soil is dug and the weeds removed.

(d) In many of the *sal* forests now under consideration the younger age-classes are usually well represented, and it is sometimes argued that :—

(1) *any attempt to introduce a method of concentrated regeneration will entail an unjustifiable financial sacrifice caused by felling immature crops or by keeping trees in the forest beyond the age of maturity which are on areas not under regeneration ;*

(2) *we need do no more at present than endeavour to bring this existing crop to maturity by means of suitable silvicultural treatment, in the hope that young growth will eventually establish itself naturally in the future as it has done in the past.*

As regards the financial sacrifice, however, it should be remembered that financial loss must be incurred unless mature trees are felled as soon as they become mature, and this cannot be done unless seedling growth is already available, or can be immediately established, to replace the felled trees. At present, it may be that the areas carrying mature or nearly mature trees with no seedling growth to replace them now on the ground are relatively small, but these areas and the consequent financial sacrifice under this head are likely to steadily increase in the future. It is probable that most of the young growth now in existence in the forests originated during, or shortly after, an era of more or less frequent fires. Whether this is so or not, however, we do know that at present practically the only way of obtaining seedling growth under shade is by burning off the annual leaf-fall and that this also is a very slow process. There is, therefore, little doubt that in areas where scarcity of labour or other conditions render it impossible to adopt the far more rapid method of artificial sowings in clear-felled areas (for which concen-

tration is obviously desirable), we shall be obliged to resort to fires to a greater or less extent in the future if we wish to avoid a steadily increasing financial loss due to the absence of regeneration in woods approaching maturity. Now, in order to minimize the damage done by fire to the standing crop, a concentration of the regeneration areas to be burnt is essential and, therefore, in order to obtain concentration and to prevent an increasing financial loss in the future some initial financial sacrifice is justified. During the period of conversion from an irregular forest to one in which a system of concentrated regeneration has been applied throughout, it would usually be possible to fell a considerable number of the trees attaining maturity in the forests not actually under regeneration, without materially increasing the irregularity of the crop or seriously interfering with the gradual introduction of a method of concentrated regeneration.

Concentration will, no doubt, at first, involve some financial sacrifice on account of the felling of some trees before they attain maturity. It must be remembered, however, that, starting as we do with a more or less abnormal forest, no matter what system of regeneration we decide to adopt, some initial sacrifice must in any case be incurred, in order that we may attain the first desideratum of scientific management which aims at attaining a maximum sustained equal annual yield, *viz.* a normal series of age-classes.

In any case, also, the introduction of a system of concentrated regeneration does not necessitate the immediate introduction of rigid uniformity at a great financial sacrifice but merely entails a series of fellings steadily tending to produce a reasonable degree of uniformity in the crop at a minimum financial sacrifice.

Moreover, some initial sacrifice is undoubtedly justified in order to obtain concentration, seeing that the latter

- (1) greatly facilitates all silvicultural work, such as cleanings, thinnings, fellings and operations for favouring the production and development of regeneration, in addition to improving the general quality of the forest.
- (2) is commercially desirable, inasmuch as it facilitates transport, and causes the aggregation of timber of a particular size and quality on well-defined compact areas.

On the other hand, seeing that *sal* is naturally a strongly gregarious tree, there is no reason to believe that such concentration will materially increase the damage done by insects or fungi, provided that the woods are properly tended. Even if such damage did increase, however, concentration would greatly facilitate control measures. That there are difficulties in the way of introducing a concentrated system of regenera-

tion for *sal*, no one acquainted with the tree will deny, so much so indeed that the attempt will almost certainly fail unless we clearly realize at the outset that the advantages of such a system, if successful, are sufficiently great to justify using making determined and, if necessary, prolonged efforts to overcome the difficulties in the way and in disregarding drawbacks which are relatively insignificant in comparison with the probable advantages.

- (e) *As full seed years do not occur every year, it may be impossible to stock an area at once after clearing and heavy weed growth may result.*

A considerable quantity of *sal* seed is produced annually, and by suitable organization of labour it should be quite possible to collect sufficient of this for the stocking of the annual regeneration area. The Dehra Dun experiments, also, have proved that a 60 feet wide strip which has been cleared for 2 years can be successfully stocked by broadcast sowing on hoed soil and also that heavy weed growth does not establish itself quickly on small patches.

- (f) *The system requires more labour than is likely to be available.*

In the *sal* forests in question labour is, as a rule, difficult to obtain during the rains, but it is believed that the only work that need be done then (in June or early July) is the broadcast sowing which obviously requires comparatively little labour.

Apart from this it will, in any case, probably be necessary to increase considerably the available labour in these forests by forest villages, or otherwise, in connection with other work of importance, such as the afforestation of extensive grasslands.

Modification of system suggested where labour is scarce.

54. Where, however, on account of scarcity of seed, insufficient labour, or other difficulties, it is desirable to reduce, as far as possible, the area to be hoed and artificially sown, it is believed that the principle of the system proposed in this paper can still be applied and that the present regeneration period can still be considerably shortened. In para. 23 (10) above it is estimated that, on an average, a full stock of *sal* seedlings cannot be obtained in the shade of the local forests in less than 40 years. If, therefore, during the 20 years immediately preceding the regeneration period, the development of seedlings in the shade is encouraged by the burning off of the dead leaves in seed years, it is probable that, at the close of this period, not less than one half of the area would be fully stocked with seedlings. The average age of such

seedlings would be 10 years and their height 15 inches (see para. 23 (9) above).

If such seedlings are then exposed to favourable conditions of soil-aeration and moisture in cleared patches and strips, as recommended in the system proposed above, it is believed that the majority of them will persist and develop vigorously. In this way, the area to be artificially sown during the 15 years of the regeneration period proper could be reduced by at least one half. This area could, if necessary, be still further reduced by lengthening the period of preparatory treatment.

In Experiment IV above, it has been shown that removing the overhead cover, in a patch 60 feet in diameter, from above 3-years-old seedlings, raised in the shade, gave very poor results, 79 per cent. of the existing seedlings dying within 3 months of the felling, see paras. 26-28 above.

In this case, however, the seedlings were only 3 years old and about 6 inches high. Ten-years-old plants 15 inches high would obviously have a much better chance of surviving.

Application of the Dehra Dun results to other forests.

55. Finally, nothing which has been said above strongly advocating the application of the modified Group-cum-Strip system, as an experimental measure, in certain selected areas is intended to prejudice trials with other methods of concentrated regeneration. The Dehra Dun experiments have, it is believed, proved that

- (1) the primary factors which prevent or retard the healthy, vigorous growth of *sal* seedlings are bad soil-aeration and drought, and the damage done by these factors can be greatly reduced by suitable fellings.
- (2) The fellings should aim at reducing the soil moisture and exposing the soil to the sun in those localities where, or at those seasons when, bad soil-aeration is most injurious.
- (3) The fellings should aim at increasing the soil moisture by facilitating the access into the soil of dew and light showers, and by diminishing water-loss due to evaporation and transpiration, through the provision of suitable side-shade, in those localities where, or at those seasons when, drought is most injurious.
- (4) In addition to the fellings, burning off the leaf-layer, hoeing the soil and judicious weeding are subsidiary operations by means of which also the soil-aeration and soil-moisture can be improved.

Based on the above results, three main methods of treatment appear to be possible, each one of which deserves attention and careful experimental trial. Each one of these methods, probably, will prove eventually to be suitable for some forests at least, while in some cases a combination of different methods may be desirable. The methods are :—

(a) *Large clearings and regeneration by artificial sowings over extensive areas.*—This method is suited to localities where the climatic conditions are generally favourable, where damage from frost or drought is not to be feared, but where bad soil-aeration is often very injurious, *e.g.* Assam, Bengal Duars and parts of the United Provinces such as Gorakhpur. This method should secure complete regeneration in the shortest possible time, combined with the greatest possible concentration of work.

Its application, however, is necessarily limited to areas where labour is plentiful.*

(b) *Clear fellings over relatively small areas in the form of patches or strips, combined with artificial sowings.*—This method is suited to localities where side-shade is necessary for the protection of seedlings from frost or drought damage, and where bad soil-aeration is liable to be injurious during the rains. It is believed that this method, which provides for a considerable concentration of work, would secure complete regeneration of the Dehra Dun forests in 15 years.

(c) *Natural regeneration under a shelter wood.*—This method, as a rule, requires a long period of time, and, probably, should only be adopted in localities where scarcity of labour or other factors render methods (a) and (b) impossible. The only way at present known of accelerating the establishment of the seedlings under this method is by burning off the annual supply of dead leaves.† It may be found advisable, in some cases, to combine this method with method (b) above. A fair stock of natural seedlings having first been obtained under shade, the overhead cover could then be removed in patches and strips as in system (b), only those areas being sown up artificially where natural seedlings have not been established.

*The system of clear-felling followed by field cultivation and finally by artificial sowings has recently been recommended for the moist *sal* forests of Bengal and Assam (*Note on Sal forests in Jalpaiguri, Buxa and Goalpara* by G. S. Hart, C.I.E., Inspector-General of Forests, Simla, 1915). Clear-felling of the existing crop in order to obtain good coppice shoots from the stools of advance growth, combined with the artificial sowing up of blanks, is in force for a part of the Gorakhpur forests under the current Working-Plan by Mr. R. G. Marriott (Allahabad, 1915) which was prepared in accordance with the proposals made by Mr. P. H. Clutterbuck in 1913.

†Burning off the leaf layer is prescribed by Mr. J. V. Collier in the current Working Plan for the Haldwani Division (Allahabad, 1917), p. 57.

The principal result of the present work has been to show that, in forests where frost damage is to be feared, *sal* seedlings can be raised from seed very much more quickly by artificial sowings in open clearings of limited extent than under shade in the forest. Even when the method of regeneration under a shelter wood is adopted, therefore, it may still be advisable to accept this principle of artificial sowings in small clearings for the regeneration of those areas where no seedlings have established themselves naturally and to regard such work as a part of the preparatory operations to be carried out before the initiation of the regular fellings.

Experiments required to indicate the precise system or combination of systems most suitable for any particular forest.

56. In order to discover what modifications of the system now suggested or what combinations of different systems are best suited for any particular forest, it seems advisable first to carry out a series of experimental fellings on a small scale, similar to those in the Dehra Dun forests reported in this paper. The experimental areas should comprise :

- (A) Small squares, the side of the square being $\frac{3}{4}$ the height of the surrounding trees.
- (B) Large squares, the side of the square being at least three times the height of the surrounding trees.
- (C) Narrow strips running due north-south, about 300 feet long and with a width equal to $\frac{3}{4}$ the height of the surrounding trees.
- (D) Similar strips to (C) but running due east-west.

These areas should be clear-felled as early as possible in the cold season, all dead leaves and débris to be burnt, existing seedlings cut out and the soil hoed at the beginning of the following hot weather. The seed to be sown broadcast throughout the experimental areas at the rate of 6 seeds per square foot of area. Sowing, if possible, to be deferred until the rains have well set in, and care being taken to see that the seed is healthy and in good condition. The sowings in any one set of experimental areas should be done as nearly as possible on the same day so that the results may be comparable. In Dehra Dun, in an average season, it is found that bad growth results in areas which get most side-shade from the south owing to the soil being there kept more or less constantly moist (*e.g.* in areas D and southern parts of A and B), that in those areas which get practically no side-shade at all (*e.g.* the central parts of area B), or only side-shade early in the morning

(e.g. the eastern side of area B), damage from drought is severe and that the best results are obtained in areas (C) which get side-shade both in the morning and afternoon, together with full sunlight at mid-day. In these forests, therefore, the modified Group-cum-Strip system, with strips running north-south, appears to be the best. In another locality in which damage from frost or drought is not severe in the central portions of areas (B), but in which the growth on the western side of these areas is obviously the best, a system of continuous strip fellings, commencing on the east and proceeding steadily through the forest towards the west, would be indicated as most suitable.

Similar experimental fellings should also be made in areas where natural seedlings are already on the ground but which are not yet fully established, in order to test the effect of such fellings in accelerating the development and establishment of such seedlings. Two or three year's careful work on these lines should clearly indicate the most suitable method or combination of methods for any particular forest, under the local conditions of climate, labour supply, nature and vigour of weed-growth, etc.

It would show, for instance, how far scarcity of labour renders it necessary to avoid hoeing and artificial sowing and to depend on the slower method of obtaining natural seedlings under shade by burning, how far it is advisable or possible to reduce weeding operations by reducing the size of the clearings, in what way fellings should best be made to accelerate the establishment of seedlings which have started growth under shade, and what method of artificial sowing is most suitable in areas where natural seedlings are not obtained in a reasonable time.

CHAPTER IV.

General Summary of Results obtained.

57. The present oecological study of the factors influencing the development of *sal* seedlings, which was commenced in 1909, was undertaken with the object of discovering a method of speeding up the growth of *sal* seedlings and of quickly regenerating the *sal* forests of northern India. The general lines on which this work has been carried out have been indicated in Chapter I above (see para 1) and the results which have been obtained up to date are now summarized below. Some of these results have already been published in previous papers but, for the sake of completeness and to facilitate reference, they have been included in the following general summary:—

- (1) *Sal* seed is particularly liable to damage from drought. Such damage can be diminished by protecting it from sun and

covering it with a layer of dry leaves or soil. If care is taken to keep it cool and to prevent it drying out, it can be stored for some weeks without injury. The writer has sent *sal* seed from Dehra Dun to Singapore which produced a good stock of healthy seedlings on arrival and which was sown one month after it had been collected, see present paper, para. 12 (8).

- (2) *Sal* seeds which are kept immersed in water fail to germinate, see present paper, para. 12 (6).

In years of heavy rainfall, germination of *sal* is best in sand and 8-30 per cent. less in water—retaining loam and leaf-mould, see *Ind. For. Rec.* V, 4, part I, 1914, paras. 17 (1), 19 (1).

- (3) *Sal* seed which is just buried in the surface soil usually germinates better than seed which is sown broadcast on the surface of the soil. In broadcast sowings, therefore, it is essential to sow thickly, *e.g.* at a rate of not less than 6 seeds per square foot of area, which should insure a fairly full stock of seedlings, even in an unfavourable season, see present paper, p. 11 (footnote) and para. 46 (3).

- (4) In a season unfavourable for germination, with an unusually short rainfall at the end of June and in July, sowings in cleared patches are more successful than sowings under shade in the forest. It is believed that this is due to more moisture being available in the cleared patches, as these get the full benefit of dew and light showers which do not reach the soil in the shady forest. In the patches, also, the evaporation of moisture is retarded by the side shade, see present paper, paras. 45, 46.

- (5) The results previously obtained by Mr. R. S. Troup and the present writer, see para. 7 of present paper, regarding the injurious effect of a soil covering of dead leaves on germination and the early growth of *sal* seedlings in the local forests, have been confirmed, see present paper, paras. 37 (2), 41 (2).

- (6) Pot cultures have shown that the injurious action of dead leaves is threefold :

- (a) a drought action, owing to the dry barrier separating the seed from the soil surface, which causes the death of the seed either before, or shortly after, germination has commenced, see present paper, paras. 9, 10, 12 (7).
- (b) a mechanical action due to the obstruction afforded by the tough leaves to the passage of the radicle.

When moisture and temperature, therefore, are suitable for the continued growth of the radicle, the latter, instead of penetrating vertically downwards into the soil, develops horizontally between the layers of leaves. In consequence of this the plants die from drought as soon as the dead leaves and surface soil dry out, see present paper, para. 12 (2) (7).

- (c) an injurious action which comes into play after the radicle has penetrated the soil and which is provisionally ascribed to bad soil-aeration. It directly causes an appreciable number of deaths and diminishes root growth. It is active in *sal* forest loam which is kept moist but is inoperative in clean sand, see present paper, paras. 14, 15, 18, 19, 20 (1) and Plate II.
- (7) Burning off the layer of dead *sal* leaves in the forest does greatly improve germination and increases the number of seedlings which survive. While not materially diminishing the number of seedlings which were on the ground before the burning, the latter appears to reduce the height growth of such seedlings, see *Ind. For. Rec.* V, 4, part II, 1916, paras. 33, 42 and present paper, paras. 22, 23 (7), 35, 36, 37 (2), 39, 40, 41 (2).
- (8) With reference to the early growth of *sal* seedlings, soil-composition is, in itself, a factor of comparatively little importance. Provided the water supply is suitable, *sal* seedlings will grow well without dying back on soils of widely different chemical and physical composition, *e.g.* sand, loam, and garden leaf-mould, see *Ind. For. Rec.* V, 4, part I, 1914, paras. 12 (4), 32, and Appendix I.
- (9) Soil moisture, however, is a limiting factor of great importance. In the experiments carried out at Dehra Dun, *sal* seedlings were found to die or die back from drought when the water-content of the soil in contact with their roots fell to 3 per cent. and below in sand or sandy loam, or to 10 per cent. and below in loam,* see *l.c.* part I, 1914, paras. 13, 14, 15

* The soil moisture death-limit probably depends to some extent on the evaporating power of the air and the rate at which the plants are losing moisture by transpiration. It was impossible, at the time, to carry out a continuous record of these conditions but the experiments here referred to were carried out (a) under shade in the cold season and (b) in the open in the hot season, *i.e.* under widely varying conditions of evaporation. As the death-limit only varied by 1 per cent. under these conditions in one and the same type of soil, it is believed that the limits here reported are approximately correct for local conditions.

- (10) In a *sal* seedling the most resistant portion of the plant, which retains vitality longest under unfavourable conditions, is the collum. This includes the insertions of the cotyledons, from the axils of which new shoots develop to replace those which die back. It is remarkable that, in *sal* seedlings, an internode often of considerable length separates the insertions of the two cotyledons, see *l.c.* part I, 1914, para. 16, p. 30 (footnote), para. 30 (6).
- (11) Drought, if sufficiently severe, suffices to kill the strongest plants. Drought of less severity, however, only kills the weakly plants and causes the so-called "dying back" of the more vigorous individuals, see *l.c.*, part I, 1914, para. 16.
- (12) In pot cultures, whereas 70—100 per cent. of the seedlings which are watered remain healthy and do not die back, 100 per cent. of those which are not watered do die or die back. This emphasizes the importance of drought as the factor responsible for death and dying back, see *l.c.* part I, 1914, para. 12 (2).
- (13) This is further emphasized by the fact that *sal* seedlings grown in the open in the Dehra Dun Experimental Garden, where the soil is kept moist by periodic sub-soil irrigation, develop vigorously from the first and do not die back. Such plants show, already in their second year, the swollen "carrot" stem characteristic of vigorously growing plants and produce an almost constant average annual height growth of 32 inches between the ages of 2 and 8 years, the most vigorous plants attaining a height of 29 feet at the age of $8\frac{1}{2}$ years, see *l.c.* part II, 1916, p. 44 and Plate II, also the present paper, para. 6 and Plate I.
- (14) During the period October-May in the local *sal* forests, the seedlings are found to die or die back chiefly in those months when the least rainfall is received. During this period, also, the moisture content of the upper soil layers frequently attains the death limit during spells of dry weather. The deaths and dying back in the local forests during these months, therefore, is believed to be due chiefly to drought,* see *l.c.* part II, 1916, paras. 18, 19.
- (15) Pot cultures have shown that, while it is practically impossible to give too much water to *sal* seedlings growing in well-

* In large clearings and open grasslands in the locality, seedlings are commonly cut back by frost in the cold season November-February, but apart from altogether exceptional seasons, such as the cold weather of 1904-05, frost does very little damage in the *sal* forests themselves.

aerated sand, seedlings soon become unhealthy in loam and leaf-mould if kept constantly moist whether by watering or by decreasing evaporation, see *l.c.* part I, 1914, paras. 12 (3), 18, 19.

- (16) In the ordinary loam characteristic of the local *sal* forests, *sal* seedlings soon become unhealthy if the soil is kept constantly moist. In ten days the less vigorous seedlings are killed and after 6 weeks 100 per cent. of the seedlings show more or less extensive death and decay of the root. Considerable root damage of this kind may occur in plants which still retain their green leaves and appear healthy above ground, see *l.c.* part I, 1914, para. 26,30 (4) (5) and Appendix II, also *l.c.* part III, 1916, paras. 5, 6.
- (17) In loam taken from a local *sal* forest and which had been consolidated by pressure, 25 per cent. more *sal* seedlings were found to die during the rains than in a non-consolidated sample of the same soil and those plants which survived were found to have an abnormal root system confined to the superficial better aerated layers of soil, see *l.c.* part I, 1914, para. 22 (2) (3) and Plate II.
- (18) When water is held in contact with the ordinary *sal* forest loam mentioned in (16) above, it becomes heavily charged with CO_2 and impoverished as regards its oxygen supply. The bad growth noted in (15) and (16) above is at present believed to be due chiefly to a deficiency of oxygen and a poisonous accumulation of CO_2 in the soil and, throughout the present work, this has been provisionally termed "bad soil-aeration."* This appears to be another limiting factor of great importance for the development of *sal* seedlings, see *l.c.* part III, 1916, para. 8.

That the limiting factor in this case is not water *per se* is shown by the fact that *sal* seedlings can be successfully grown in water cultures, see *l.c.* part III, 1916, para. 14.

- (19) Sowings in the local *sal* forests in 1912, 1913, 1915, 1916, 1917 and 1918 have shown that seedling development is invariably better, both in favourable and unfavourable seasons, in cleared patches and narrow strips with full overhead light and side-shade than in the shade plots where the overhead cover was not removed. In the shade plots,

* Results of further work dealing with the influence of CO_2 and oxygen on the root growth of seedlings in water cultures will shortly be published in another paper, see also *Agricultural Journal of India*, Vol. XIII, Part III, pp. 433-436, July 1918.

in all cases, the surface covering of dead leaves and humus was carefully swept off before sowing, see *l.c.* part II, 1916, paras. 14, 22, 36, Plates III, IV, V, VI, VII, IX and present paper, paras. 22, 23 (6), 23 (8), 31, 32 (1), 36, 37, 40, 41 (4), 41 (5), 45, 46, Plates III, IV.

- (20) During the rains, the soil (upper 6 *ins.* layer), in the shade plots, invariably contained more water and organic matter than that of the open plots and this was correlated, in the shade, with more deaths during the rains (accompanied by more or less extensive root rot) and more deaths from drought in the dry season as a direct result of the poor root development in the rains. The inferior results in the shade plots, therefore, are believed to be due mainly to bad soil-aeration, see *l.c.* part II, 1916, paras. 16, 19, 22, 23 (2), 23 (5).
- (21) The inferior growth of *sal* seedlings on loam, in the shade, during the rains, can be improved by exposing the soil to the air and preventing the accumulation of dead leaves, see *l.c.* part II, 1916, para. 23 (4).
- (22) The inferior results in the shade are not primarily due to deficient light, inasmuch as good seedling growth has been obtained in the Dehra Dun garden under artificial shades giving a light intensity less than that in the darkest experimental plot. Excellent seedling growth has also been obtained in the forest shade plots in a year of good rainfall by sowing in pots filled with sand,* see *l.c.* part II, 1916, paras. 13, 15, 28 (2).
- (23) The growth of *sal* seedlings in sand, both in the shade and in the open, is improved by the addition of dead *sal* leaves to the sand. This increases the water content of the sand, diminishes deaths from drought and produces more vigorous seedlings, as judged by the height and dry weight of the stems and length of the roots, see *l.c.* part II, 1916, paras. 27, 28 (5) and present paper, paras. 18, 19.
- (24) The greatly superior results obtained in the cleared patches and strips, as compared with those obtained under shade, see (19) and (20) above, are, therefore, mainly due to two factors :

* As regards this point, it must be remembered that, in a year of short rainfall, the seed and seedlings in sand are likely to suffer from drought and, in order to secure good results in such years in sand, artificial watering is necessary. See also (15) above,

- (a) Improved soil-aeration and consequently stronger root growth during the rains, owing to the partial drying out of the soil in the clearings during the intervals of hot sunshine.
 - (b) Moister soil in the clearings during the cold and dry season. This is caused by the addition of water to the soil in the form of heavy dew and light showers, while water loss by evaporation is retarded by the side shade afforded by the adjoining trees. Very little dew or light rain reaches the soil under the shade of trees during this period which consequently remains much drier than that of the clearings. The moister soil naturally helps the plants in the clearings to withstand the hot dry season. These results, therefore, indicate that the two factors of outstanding importance which affect the healthy development of *sal* seedlings in this locality are drought and bad soil-aeration,* see *l.c.* part II, 1916, paras. 19, 23 (5) and present paper, para. 23 (3) (4).
- (25) Removing the overhead cover in patches, 60 feet in diameter, from above 3-years-old seedlings raised in the shade results in a high percentage of deaths (79 per cent. of the existing seedlings) and weeding becomes necessary two years after the felling to prevent the suppression of the surviving plants. This indicates that seedlings raised in the shade should not be freed from overhead cover until they are considerably older than 3 years, see present paper, paras. 27, 28.
- (26) Sowings in areas where the overhead cover has been broken give inferior results to those obtained from sowings in completely cleared narrow strips, see results in Plots XXVI and XVII, paras. 40 and 41 (5) (7) above.

* In a letter to the writer dated 28th August, 1917, Singapore Botanic Gardens, Mr. I. H. Burkill writes as follows: "We are having very wet weather and it shows how your observations on the need of soil-aeration can be extended from *Shorea robusta* to *S. macroptera* and *S. rigida*, for there is a great mortality proceeding among last year's seedlings in the Gardens Jungle."

Mr. R. S Troup, also, has recently ascribed the failure of *sal* regeneration in the moist forests of Bengal and Assam to bad soil-aeration. (*Note on the Forests of the Duars*, Simla 1915, p. 36.)

It is interesting to note that, apart from the question of the establishment of seedlings, Mr. R. G. Marriott has recently attributed the poor development of older trees to this factor, and suggests that, owing to it, the trees may practically cease to grow during the rains which ought to be the period of most vigorous growth (*Indian Forester* XLIII 1917, p. 444.)

These observations indicate that the need for good soil-aeration is not merely a factor of local interest but is a widespread phenomenon of general importance.

- (27) In some cases where the ground is fairly level and the soil surface has not been hardened, quite good results may be obtained on loam from broadcast sowings on undug soil. When on loam the ground is not level, the seed is liable to be washed away by the rain, whereas in dug soil the rainfall percolates *in situ*, an equable distribution of moisture in the soil is secured, the seeds are not washed away and a well distributed stocking with vigorous plants is secured. To obtain uniformly good results on loam, therefore, hoeing is necessary, see present paper, paras. 36, 37, 40, 41 (3), 45, 46 (2).
- (28) The larger the cleared areas, the stronger the resulting growth of weeds and the greater is the damage to the seedlings by drought. On the whole, the best width for the cleared strips and patches is $\frac{3}{4}$ ths the average height of the adjoining trees. In openings of this kind frost does no damage. In order to diminish trouble from weed growth it is desirable to regenerate small cleared patches first and then to gradually extend these areas in the form of narrow strips, see *l.c.* part II, 1916, paras. 35, 37 (3) (4) and present paper, paras. 30, 31, 32 (2) (5) (6) (7) (9) (10) and Plate V.
- (29) The experience gained in experiments V and VII above indicate that, in the small cleared patches, one or at most two weedings will be sufficient. In the larger clearings it is believed that four weedings will be sufficient, one at the end of the first rains, one at the beginning and end of the next rains and one during the next two years. Weeding should be done with discrimination and in the larger clearings scattered plants of the larger tufted grasses (*Saccharum*, *Erianthus*, etc.) or a few woody coppice shoots (which can be topped when necessary) are often beneficial in decreasing water loss from the plants and in preventing the development of the highly injurious matted growth of small herbaceous plants, see present paper, paras. 31, 32 (9), 32 (10) and Plate VI.
- (30) In the forests in which these experiments have been carried out, in a year of normal heavy rainfall (60 ins. and above during the period June-September inclusive), side shade from the south is decidedly injurious by keeping the soil perpetually moist, which causes the plants to suffer from a badly aerated soil and from the attacks of leaf—and twig-killing fungi. Bad results are also obtained in areas which

receive no side-shade from the east, west or south, a large number of plants dying in such places from drought in the dry season. On the other hand, uniformly good results are obtained in areas which receive a considerable amount of side-shade both in the morning from the east and in the afternoon from the west. In these forests, therefore, the shade from the south side of patches should be diminished and the strips should run in a north-south direction. This insures shade on the area during the morning and afternoon with full sunlight during midday, which prevents excessive dampness of the soil, see present paper, paras. 23 (1) (2), 32 (4), 32 (5), 32 (6), 39.

- (31) The average annual height growth of *sal* seedlings which can be obtained in the locality under various conditions is shown below, as calculated for the first five years from the measurements of seedlings of known age:—

Conditions.	Average annual height growth in inches.
1. Practically ideal conditions of moisture, light, soil, and absence of weed competition in the Dehra Dun Experimental Garden, present paper, para. 6.	32
2. On a small scale in the forests in cleared patches, under unusually favourable conditions, present paper, paras. 22, 23 (6).	10
3. On a comparatively large scale, by broadcast sowing on hoed soil in the forest, on cleared strips in an average season, present paper, paras. 41 (5) (6), 42 (5) (6).	8.6
4. Under shade in the local forests, present paper, para. 23 (9) . . .	1.5

- (32) Based on the results of the experimental work which have been summarized above, a system of regeneration has been suggested for the type of *sal* forest here dealt with, which, it is believed, will reduce the regeneration period by not less than 35 years. It is suggested that an attempt should be made to apply this system in one or two selected areas, as an experimental measure, on a small scale. The system is a modified combination of the group and strip systems, see present paper, paras. 48, 49, 50, 51.

- (33) Various objections to the proposed system are discussed and a modification of it is suggested for areas where scarcity of labour, or other difficulty makes it necessary to reduce the area artificially sown, as far as possible, see present paper, paras. 52, 53, 54.
- (34) Finally, it is suggested that, in order to discover what modifications of the system are most suitable for any particular forest, a series of preliminary experiments should be carried out for two or three years in the forest in question. These experiments are detailed in the present paper, para. 56.

APPENDIX.

Analyses of soils used in Sal experiments, 1915—1919.

Description of sample.		Loam from Dehra Experimental garden. Upper 9 ins.		Sal Forest (Lachiwala) loam. Upper 1 foot.				Sand from Song river (near Lachi- wala). Upper 1 foot.	REMARKS.
Designation of sample.		A	B	C	D	E	F	G	
CHEMICAL ANALYSIS.									
Moisture . . .		2.45	2.37	2.41	2.23	2.24	2.53	.53	A and B soil used in experiment I see para.6.
Organic matter . . .		5.40	5.21	6.33	6.56	5.54	5.93	2.14	
Nitrogen . . .		.059	.057	.117	.095	.108	.105	.033	
Potash . . .		1.51	1.89	1.45	1.40	1.00	.82	.37	C—F soil used in experiments II— VIII.
Potash, soluble in 1 per cent. citric acid.		.017	.013	.038	.058	.063	.061	.05	
Lime . . .		.68	.69	.83	.85	.63	.54	3.14	
Magnesia . . .		1.88	2.60	1.22	1.10	1.30	1.10	2.66	G sand used in experiments II(a) and II(d)—see paras. 8, 17.
Alumina . . .		7.67	5.05	3.20	4.88	5.76	5.33 }	3.7	
Ferric oxide . . .		6.75	10.19	11.84	7.75	6.51	7.38 }		
Oxide of manganese . . .		.22	.10	.64	.49	.41	.26	.07	
Calcium carbonate . . .		.59	.50	1.48	1.48	1.12	.98	6.83	
Phosphoric acid . . .		.117	.116	.10	.07	.11	.06	.07	
Phosphoric acid soluble in 1 per cent. citric acid		.008	.007	.026	.033	.036	.032	.008	
Sulphuric acid . . .		.19	.20	.10	.11	.06	.06	.1	
Reaction . . .		Acid	Slightly acid.	...	...	...	...	Neutral	
MECHANICAL ANALYSIS.									
PRELIMINARY MECHANICAL ANALYSIS.	Stones . . .	.48	.04	...	.02	...	...	...
	Air-dried fine earth . . .	99.52	99.96	100.00	99.98	100.00	100.00	...	
		100.00	100.00	100.00	100.00	100.00	100.00		
MECHANICAL ANALYSIS.	Fine gravel . . .	.25	.11	...	.09	.03	.10	...	
	Coarse sand . . .	12.88	9.86	2.13	3.32	3.02	2.95	...	
	Fine sand . . .	15.64	17.26	24.47	19.86	19.85	21.57	...	
	Silt . . .	20.82	20.25	32.17	39.49	38.30	35.75	...	
	Fine silt . . .	21.38	23.49	15.63	13.73	16.22	15.80	...	
	Clay . . .	19.80	20.11	13.58	11.22	11.71	11.10	...	
	Solubles in water . . .	1.12	1.12	3.23	3.45	3.06	4.22	...	
	Hygroscopic moisture . . .	2.45	2.37	2.41	2.23	2.24	2.53	...	
	Organic matter . . .	5.40	5.21	6.33	6.56	5.54	5.93	...	
	Carbon dioxide . . .	.26	.22	.05	.05	.03	.05	...	
		100.00	100.00	100.00	100.00	100.00	100.00	...	
	Soluble humus . . .	2.74	2.53	3.33	3.05	2.92	2.56	..	



Fig. 1. Several of the *Sal* seedlings in pots 14 and 19 have shed their leaves as a result of placing dead *Sal* leaves on the surface of the soil. In pots 15 and 18, to which no dead leaves were added, the seedlings are quite healthy. Photograph taken $3\frac{1}{2}$ months after the dead leaves were added.



Fig. 2. Photograph of *Sal* seedlings growing in sand, taken $3\frac{1}{2}$ months after a layer of dead *Sal* leaves had been placed on the surface of the sand in pot 23. No dead leaves were added to pot 22. No injurious effect has been produced by the dead leaves. See present paper para. 19.



Fig. 1. Forest plot IV. An area 60 feet in diameter was here clear-felled in May 1913. The photograph was taken from the south-west looking towards the north-east on 20th July, 1915. Note the vigorous 2-years-old seedlings surviving in the plot. After 2 years of short rainfall the growth in the southern half of the plot is better than that in the northern half.



Fig. 2. Forest shade plot V. Photograph taken 20th July, 1915. Note the appearance of the 2-years-old *Sal* seedlings surviving in the plot. See present paper paras 21, 22, 23.



Fig. 1. Forest plot IV. The photograph was taken on January 31st, 1919, from the south-west looking towards the north-east. Note the vigorous seedlings now 5½ years old, surviving in the plot. After 3 years of normally heavy rainfall, the growth in the south-

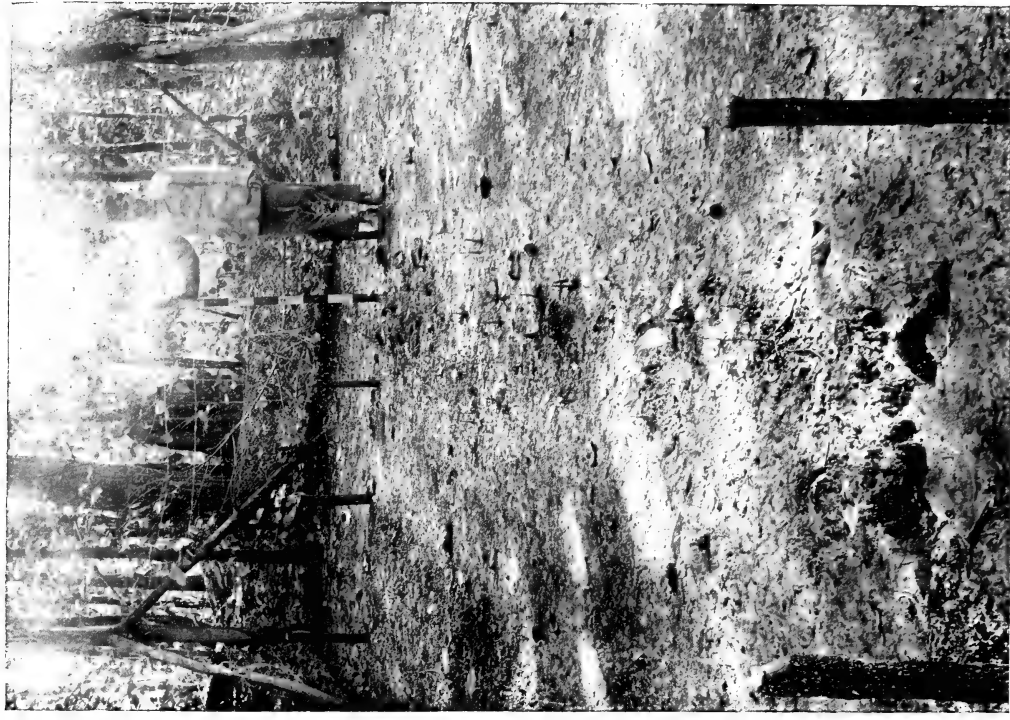


Fig. 2. Forest shade plot V. Photograph taken on January 31st, 1919. Note the appearance of the seedlings, now 5½ years old, surviving in the plot. See present paper paras. 21, 22, 23.



Fig. 1. Lachiwala Plot XIX, a square with side of 60 ft., which was clear-felled in May 1915. Photograph was taken in December 1917, i. e. after $2\frac{1}{2}$ years. Note the absence of heavy grass and weed growth.

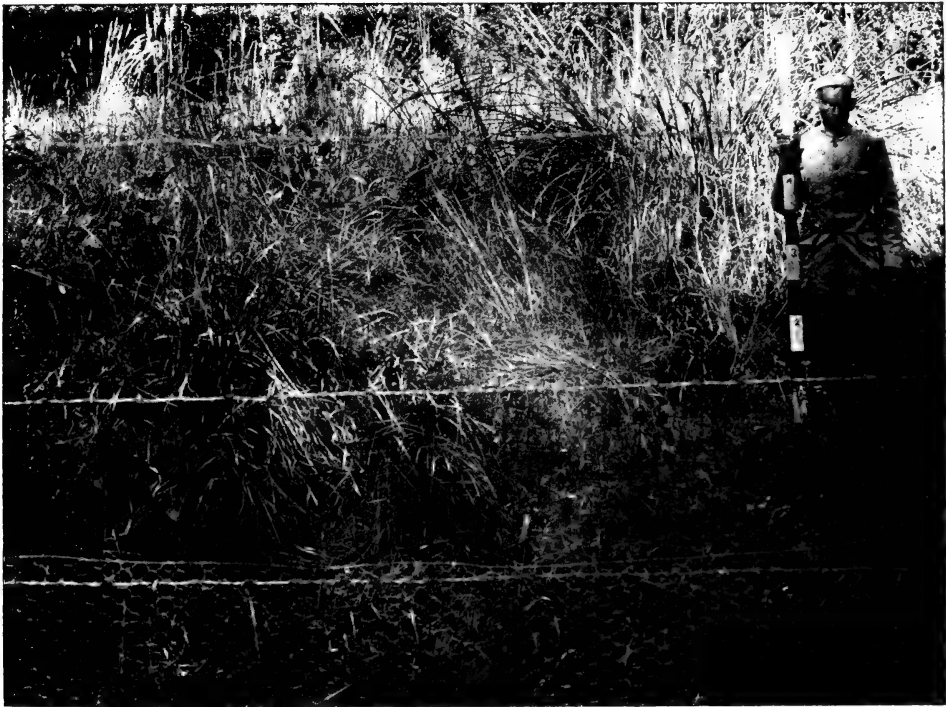


Fig. 2. Lachiwala Plot XX, a square with side of 180 ft., which was clear-felled in May 1915. Photograph was taken in December 1917, i. e. after $2\frac{1}{2}$ years. Note the dense growth of grass and weeds. See present paper paras 30, 31, 32.





Fig. 1. Centre bed of Plot XVIII (a strip 300 ft. long and 100 ft. wide, running north-south) showing *Sal* seedlings now $3\frac{1}{2}$ years old. Note that some seedlings of exceptional vigour have established themselves in the unweeded portion of the bed among the coarse grasses near the measuring staff on left. The area on the right has been kept weeded. The boundary of the bed has been cleared of grass to facilitate the photograph. Photograph taken 31st January, 1919. See present paper para. 32(10).

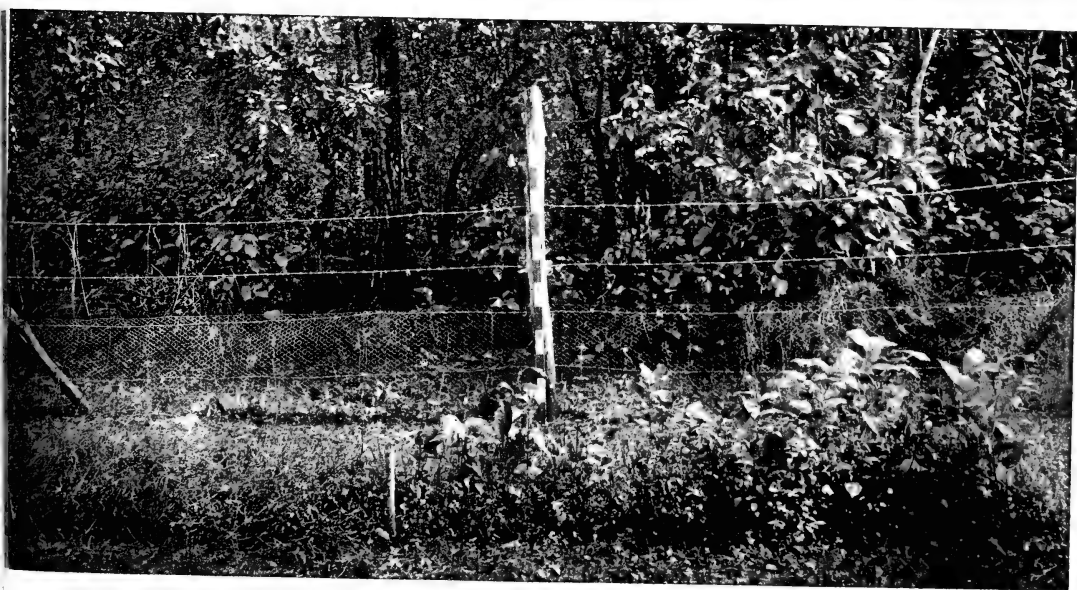


Fig. 2. A fenced area sown with *Sal* in June 1915. Photograph taken 31st January, 1919, when seedlings were $3\frac{1}{2}$ years old. In the unweeded portion to the left of the peg the *Sal* seedlings have been entirely killed out by a matted growth of *Ageratum*, in the weeded portion to the right of the peg some plants have survived but show poor growth. *Ageratum* gives no trouble whatever in this locality in unfenced areas. See present paper para. 32 (10).



Fig. 1. Shade Plot XXV utilised in experiment VII. The overhead cover was left intact but the undergrowth was removed in May 1917. See present paper para. 39.



Fig. 2. Shade Plot XXVI utilised in experiment VII. In May 1917, in addition to removing the undergrowth, the overhead cover was broken, an average space of about the diameter of one crown being left between the crowns. See present paper para. 39.

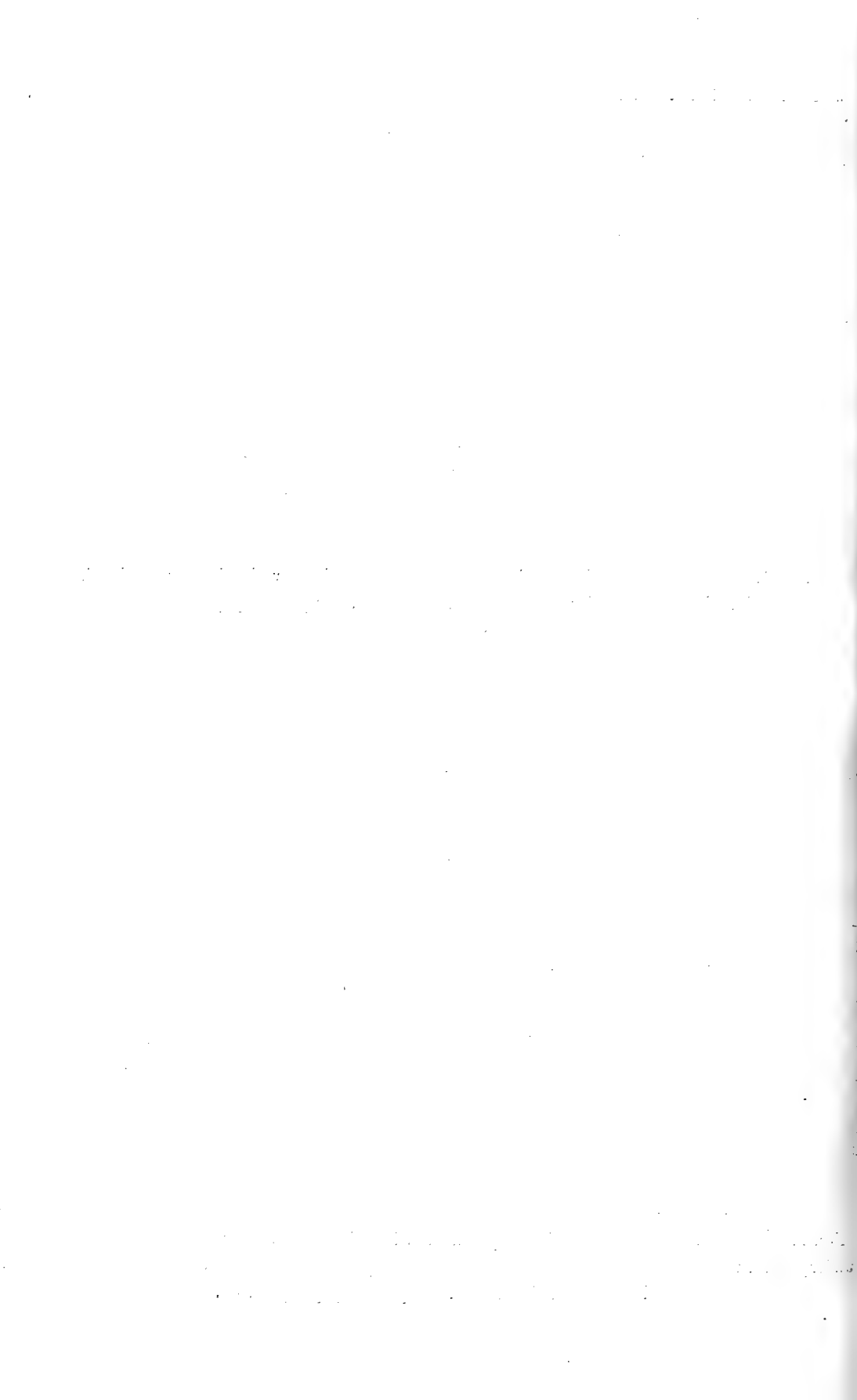




Fig. 1. Showing *Sal* seedlings, $1\frac{1}{2}$ years old, in January 1919, resulting from broadcast sowing in Plot XVIII, I(c), (100 feet wide strip), in experiment VII. See present paper paras. 39, 40, 41.



Fig. 2. Showing *Sal* seedlings, $1\frac{1}{2}$ years-old, in January 1919, resulting from broadcast sowing in Plot XVII, II (c), (60 feet wide strip), in experiment VII. See present paper paras. 39, 40, 41.

7

INDIAN FOREST RECORDS

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[Part III

THE BEEHOLE BORER OF TEAK.

**A Preliminary Note on the Ecology and Economic Status
of *Duomitus ceramicus*, Wlk. in Burma.
(*Lepidoptera; Cossidae*).**

BY

C. F. C. BEESON, M.A., I.F.S., F.E.S.,

Forest Zoologist at the Forest Research Institute, Dehra Dun.

INTRODUCTION

THE investigations carried out by the Forest Zoologist on the ecology of the beehole borer of teak, *Duomitus ceramicus*, Wlk., have been limited to three tours carried out in Burma between the following dates: 25th March—20th May 1914, 7th May—24th June 1918 and 15th April—13th June 1919, together totalling 137 working days. As the insect is a pest of living trees the investigation of its life-history has necessarily been confined to the forests of its natural habitat, and no experimental work has been possible in the laboratory or insectary at Dehra Dun. The first tour yielded evidence on the life-cycle and general bionomics, and, with this as a basis, the later visits were devoted to sampling the ecological conditions as widely as possible in the restricted time available, in order to discover the range and variety of problems awaiting intensive research, and to obtain a rough idea of the incidence of the chief factors. The present note is of the nature of a preliminary report, and does not claim to give a complete account of

the seasonal history of the insect, or to have solved the problem of its control. Before this is possible it will be necessary to establish experimental stations and permanent observation areas, and to collect statistical data on an extensive scale. The enquiry has almost reached the stage at which it becomes sylvicultural rather than entomological, and it is believed, that if the research methods outlined here are utilised, much of the required statistical information can be obtained in the absence of expert entomological assistance. There is, nevertheless, occupation for 2 years for a whole-time entomologist working on this pest alone.

In urging upon everyone concerned the extreme importance of a thorough investigation into the beehole borer of teak it may be of interest to state that the calculated losses to Government, on teak timber extracted departmentally, are placed at ten lakhs of rupees annually. If the losses to firms are added the total annual losses must reach three or four times this amount. Even allowing for considerable error in calculation, the gravity of the problem, in view of a possible reduction in the output of teak, cannot be overlooked and it behoves the Forest Research Institute in association with the Forest Department in Burma to spare neither men nor funds in an endeavour to work out the life-history of this forest pest and to devise control measures. The subject is of more than local interest as it involves the maintenance of supplies of a timber which plays an important part in our national security and trade.

The writer wishes to express his indebtedness to the Chief Conservator, Conservators, and Divisional Officers of Burma for assistance in arranging tours, transport, labour, etc., and for valuable advice and information. Opportunity is also taken to record his appreciation of the work of the Forest Zoologist's touring staff on unfamiliar ground and under trying climatic conditions.*

* Submitted for publication on 28th November 1919,

PART I.

Previous History of the Pest and Economic Aspect of the Damage.

By

A. RODGER, O.B.E.,

Forest Research Officer, Burma.

[At the request of the Forest Zoologist, Mr. A. Rodger, Forest Research Officer, Burma, kindly supplied the following information on the past history of the bee-hole borer in Burma and the economic aspect of the damage done by it.]

1. The damage done by this insect has been fully recognised in Burma ever since the trade in teak was organised by Europeans. The name evidently arose from the idea that a wood-wasp or humming beetle made the holes, as those insects had been supposed to bore holes in bamboos and soft woods. The effects of the attack seem to have been accepted as a natural phenomenon and no attempt appears to have been made for many years to investigate the history of the moth, and the consequent effect on the forest. The first notes of the damage caused, appear to have been made in 1841 and 1851. These will be found below, page 5, extracted from a report by Mr. Branthwaite, Conservator of Forests, Tenasserim Circle. In the proceedings of a forest conference held in Rangoon in 1875 the subject is not mentioned, and the earlier reports by Sir Dietrich Brandis it does not seem to have received any attention. In the Annual Report on Forest Administration in British Burma for 1863-64 by Mr. H. Leeds, the following note occurs:—"It is certain that a large number of young trees are killed by small worms which attack the stem and feed on the pith. Many young plants were collected for examination showing the perforations made in them and the injuries inside which had resulted in the destruction of the plants." This may possibly refer to the bee-hole borer.* The following notes are extracted from the Annual Reports for 1901-02:—

- (1) "The damage done by insects in teak plantations was the subject of careful enquiry by Mr. S. Carr, Deputy Conservator of Forests, whose report has been forwarded to the

* It is more probable that this record refers to one of the pith-borers of teak, e.g., *Alcidodes ludificator*, Fst. or the early stages of *Phassus signifer* Wlk. and *Haplohammus cervinus*, Hope. The attack of *Duomitus ceramicus*, Wlk. very rarely causes the death of young plants and is invariably confined to wood in which heart wood is beginning to appear. See also page 49. C. F. C. B.

Forest Entomologist for information and classification of specimens.”*

- (2) “ Teak trees in the Bhamo and Katha divisions are very liable to the attacks of some wood-borer which causes what are known as bee-holes. Planks cut from apparently sound logs are often found riddled with holes the size of a lead pencil. Certain forests have a very bad reputation, and timber from these is almost unsaleable. Very large sums are annually lost from this cause, and the Inspector-General of Forests was asked whether the services of the Government Entomologist could not be spared to investigate the matter. It is certainly worthy of study, for it is useless to spend money on trees which may later be found to be quite valueless.”

The Annual Report of the Northern Circle for the year 1902-03 contained the following:—“ With reference to the remarks made in paragraph 40 of last year’s report regarding “ bee-holes ” in timber from Katha and Bhamo, although a specimen of the bee (*Xylocarpa* sp.), supposed to cause this damage was received from the London Museum, no one here seems to recognize the insect and all endeavours to collect a specimen have failed.”

In the report for the same circle for 1903-04, the following occurs, “ Further search was made for the boring insect which causes the ‘ bee-holes ’ so abundantly met with in Kadu. Whilst converting some refuse teak the larvæ and pupæ of some insect resembling a Longicorn beetle were found at the end of one of the borings. Unfortunately they did not hatch out but specimens of the borings with the remains were sent to Mr. Stebbing.”

The discovery of the identity of the insect was reported by the Conservator of Forests, Northern Circle, in 1904-05 in the following words:—“ The most interesting feature of the year, however, was the discovery of the so-called “ bee-hole borer ” in teak. This had been looked for years, and the damage was generally supposed to be caused by either the larva of a bee or beetle. Mr. Stebbing, the Government Forest Entomologist, however, paid a visit to this province in February, and in the Mohnyin Reserve of Katha Division, the teak timber from which is renowned as being more bee-holed than timber from anywhere else, succeeded in discovering the author of the injury which turned out to be the larvæ of a moth “ *Duomitus* sp.” a moth

*This report refers only to defoliators, principally *Hyblosa guera*. C.F.C.B.

allied to the goat moth of Europe so destructive to the willow. It is, however, doubtful whether any remedial measures can be adopted."

Mr. Stebbing published a short note containing an account of his discovery in 1905.* After this date references to the insect occur frequently in the Burma Annual Reports, and it appears to be accepted that it is found throughout the Province in teak forests. Mr. Hauxwell wrote in 1907-08. "A new species of teak-borer was discovered by the writer during the year; a beetle, a new form of *Aeolesthes*, was discovered in a boring, while a teak log was being sawn up. Unfortunately until the larva and female are found it will not be possible to finally identify it;" and Mr. Branthwaite's report for the same year on the subject runs thus:—

"In the Toungoo Division not only was the bee-hole borer (*Duomitus ceramicus*) found in the older teak plantations, but the teak leaf roller *Hybloea* was also noticed in many parts of the division. In the Thaungyin Division the defoliating caterpillar (*Pyrausta nacheoeralis*) is reported to have attacked many of the plantations. The teak logs from this division cut up by Messrs Steel Brothers are reported to be much damaged by "Bee-holes" which render a great proportion of the timber unfit for the European market. As long back as 1841, Captain Tremenhoe mentioned in a report on the Thaungyin Forests that the stem of the teak was attacked by a beetle which bored teredo-like holes and later in 1851, Dr. Falconer, Superintendent of the Botanical Gardens, Calcutta, in his report in the Tenasserim Teak forests† recorded that "logs flawed with holes and clefts from the Thoungyen in the Shipments made to England is generally considered to have been the cause of the bad repute into which the Tenasserim teak has fallen at home for ship-building, as compared with Malabar teak." Probably the "Bee-hole borer" was then at work in the natural mixed forest so that there is grave cause for anxiety concerning the timber grown in the pure teak plantations made in this valley."

[Further mention is made in a report dated 20th June 1845, by Captain Guthrie, Superintendent of Forests, Tenasserim Provinces, who says of the Thaungyin teak that "it appears to be somewhat liable to small cells, isolated, but which appear on sawing up." C. F. C. B.]

In the Annual report for 1914-15 we find a record of the beginning of systematic investigation. "As a result of the tour made by the Forest Zoologist in this province last year, steps are now being taken for the methodical investigation of the life history of the bee-hole borer

* Forest Bulletin [Old Series], No. 1, 1905.

† Falconer, 1851, paras. 38, 41.

(*Duomitus ceramicus*)” and this is continued in 1915-16 thus:—The damage done by the “Bee-hole borer” *Duomitus ceramicus*, is especially serious as the timber attacked is always depreciated and sometimes ruined. Observation Stations for the study of its life history have now been established in North Toungoo (Pyonchaung Reserve), South Toungoo (Bondaung Reserve), Bhamo (Okkyi) and Pyinmana (Yanaungmyin Reserve). Observations have been made and recorded; but further progress is somewhat at a standstill owing to the deputation of the Forest Entomologist to Mesopotamia.

Mr. Beeson has been in charge of the investigation since 1914. [The investigations carried out by the Forest Research Institute have been limited entirely to field-work. A tour was made in April-May, 1914 in which the life-history of the borer was worked up and a scheme outlined for future field-work involving the establishment of permanent sample plots and observation areas. This information (Forest Zoologist’s Report No. 708—106-13, dated 15th November, 1914) was printed for distribution to divisional officers in Burma, and the proposals relative to extended field surveys were approved by the Chief Conservator. Three officers Messrs A. R. Villar, Deputy Conservator, R. Unwin, Assistant Conservator, and W. C. Rooke, Extra Assistant Conservator, were deputed in 1916 to carry out special investigations on the ecology of the borer, in Shwegu, Pyinmana and North Toungoo. Observation areas were also started by Mr. N. V. Holberton, Deputy Conservator in South Toungoo, and by Mr. A. Rodger, Forest Research Officer in Zigon. The information collected by these officers is incorporated in the present note. In 1917, owing to the claims of war work no further progress was made.

In May-June 1918, the Forest Zoologist collected statistical data on the incidence of the borer, and inspected the observation areas in the Pegu Yomas. The Report on the Bee-hole Borer Investigations of 1918 was printed and circulated in the province. The data on the incidence of the borer in plantations proved somewhat alarming, in view of the policy relating to the production of teak in pure crops, and an extension of the investigation was ordered. A further tour in April—June, 1919 was devoted to sample plot analyses in seven localities. The year was also productive of much valuable information on the distribution and abundance of the borer, contributed by timber lessees and divisional officers.

At the request of the Forest Research Institute, Buitenzorg, Java, for information on the bee-hole borer, the Forest Zoologist placed his unpublished notes at the disposal of that institute. These were extensively reproduced, with courteous acknowledgments by Mr. H. Beekman,

Directeur V/h Boschproefstation in his note on the pest in Java, "*De groote djati-boorder (oleng-oleng)*, *Duomitus ceramicus*, *Wlk.*" (Meded. V/h proefstation voor het Boschwezen, 4, 1919), who has kindly permitted the reproduction of one of the plates illustrating the note. C. F. C. B.]

2. With a view to obtaining the opinions of the large number of experts who are employed by the important timber firms in Burma, the managers were asked to collect and forward any information of value that had been or could be collected. The information obtained has been summarised below and the writer gratefully acknowledges his indebtedness to the following firms: Messrs The Bombay Burma Trading Corporation, Ltd., Messrs Steel Brothers & Co., Ltd., Messrs T. D. Findlay & Co., Ltd., and Messrs Foucar & Co., Ltd.

3. The word "bee-hole" appears to have been employed by Europeans from the earliest times of which there is any record, and means a hole of moderate size made by any boring insect. It does not include teredo borings nor holes made by small beetles in the sapwood. [On the specific identity of insects causing beeholes in teak and their differentiation, see p. 49. C. F. C. B.]

4. The number of bee-holes that may be found in a log varies very much. As many as 88 bee-holes have been recorded in one log, and this number has almost certainly been exceeded. [Logs examined by the Forest Zoologist in a Rangoon saw mill revealed from 100-400 beeholes on the exposed faces of the planks and beams; analyses of whole trees indicate that a total of several hundred beeholes per tree is not infrequent. C. F. C. B.]

A square which without bee-holes would be called Europe quality may be relegated by their presence to inferior Indian Grade. One firm reports as follows:—"The logs which show bee-holes or even one bee-hole on the butted end, generally open up very bee-holey, and I judge that these bee-holes are made chiefly during the earlier part of the life of the tree, for where a log shows bee-holes, after the first slab has been cut off it, it is almost invariably the case that the next cut will open up a much larger number of bee-holes, so that one might make the broad statement that in 9 cases out of 10, bee-holing increases the nearer one gets to the heart of the tree." Bee-holes in the middle of a log, plank, or board are more harmful than at the ends or edges, and the position and number of these blemishes are very carefully examined when a log is on the saw-mill benches.

5. Taking a general average for the Province, it is probable that the value of the Annual Outturn of teak is lessened by 10 to 15 per cent. by the fact that the bee-hole borer attacks the teak tree. During the

year ending 30th June 1918, 378,000 tons of teak were extracted, on which Government received 91½ lakhs of rupees. As a rough guess, it would not be far wrong to say that, did the bee-hole borer not exist, Government would have received one crore of rupees on the same outturn, and the profits of the owners or buyers of the timber would have increased at least to the same extent.

Synonymy of the species.

Genus DUOMITUS, Butler, (1880).

Zeuzera ceramica, Walker, (1865), Cat., xxxii, p. 587. (♂)

Duomitus ligneus, Butler, (1880), Ann. Mag. Nat. Hist., (5), vi, p. 68.

Duomitus ligneus, Butler, (1886), Ill. Lep. Het., vi, p. 29, pl. cviii, fig. 3. (♀)

Duomitus ligneus, Cotes and Swinhoe, (1887), Cat. Moths Ind., i, p. 234, No. 1599.

Duomitus ligneus, Kirby, (1892), Syn. Cat. Lep. Het., i, p. 877.

Strigoides ceramica, Swinhoe, (1892), East. Lep. Het., i, p. 280, No. 1295.

Duomitus ceramicus, Hampson, (1892), Fauna Brit. Ind., Moths, i, p. 307.

Duomitus ceramicus, Dudgeon, (1899), Jour. Bom. Nat. Hist. Soc., xii, p. 645.

Duomitus ceramicus, Stebbing, (1905), Forest Bulletin No. 1, and Ind. For. xxxi, Appendix, pl. i-iii.

Duomitus ceramicus, Stebbing, (1908), Man: For. Zool., p. 127, pl. iv.

Duomitus ceramicus, Beekman, (1919), Meded. v. h. Proefst. v. h. Boschwezen, 4, pp. 3—20, pl. 1-6.

Food-Plants.

Teciona grandis, Linn., in Burma and Java.

The writer has searched unsuccessfully for alternate food-plants in forests in which the borer was abundant, directing special attention to *Gmelina arborea*, Roxb. (Verbenaceae), because other borers of teak, viz., *Haplohammus cervinus*, Hope, *Glenea galathea*, Thoms., *Phassus signifer*, Wlk. and others have been bred from it. The distribution records for *Duomitus ceramicus* beyond the habitat of teak may be questioned, but if correct they indicate undoubtedly the existence of other food plants.

Seubert [1902] in a postscript to Salverda's note on the insect pests of teak plantations in Java records *Spathodea campanulata*, Beauv., a tropical African tree largely cultivated in the East, as a host of *Duomitus ceramicus*. Beekman [1919, p. 12] however, points out that the former's observation has not yet been confirmed from any other source. The reviewer of "Indian Forest Insects" [Jour. Bom. Nat. Hist. Soc., xxiii, 1915, p. 765.] says that "*Duomitus ceramicus* also attacks fig trees of many species," but he subsequently informed the Forest Zoologist that this statement is incorrect.

The genus *Duomitus* is essentially a wood-boring genus; the food-plants of known species are:—

armstrongi, Hamps. Coffee in the Gold Coast, [Hampson, 1914, p. 245.]

capensis, Baker. Castor oil plant in Zanzibar, [Aders, 1916, p. 49]; *Cassia didimobotrya* in Brit. E. Africa, [Deakin, 1916, p. 244.]

leuconotus, Wlk. *Cassia nodosa* in India, [Stebbing, 1902, p. 428]

Cassia grandis in Ceylon, [Speyer, 1918, p. 10.]

lituratus, Don., *Ficus* spp. in Australia, [Seitz., 1912, p. 418.]

punctifer, Hamps. *Achras sapota*, *Anona muricata*, *Cinamomum camphora*, *Citrus* spp., *Codiaeum* spp., *Gliricida maculata*, *Ipomoea* spp., *Malphigia glabra*, *Pithecolobium saman*, *Tecoma leucoxydon*, in the Lesser Antilles, [Agric. News. Barbadoes, 1914.]

strix, L., *Agati grandiflora* in Celebes, [Suellen, 1876, p. 22.]

Distribution.

Localities :—Sikkim ; Burma ; Singapore ; Java ; Nias ; Ceram ; British New Guinea ; Trobriand Is.

The distribution of *D. ceramicus* in Burma recorded in the following pages is based on information supplied by forest officers and timber lessees from 1913 onwards, but mainly in reply to circulars issued in 1913 and 1919. As considerable diversity of opinion exists about the occurrence and the conditions governing the local abundance of the pest, and apparent contradiction is not infrequent, I have thought it desirable to reproduce the information *verbatim* in many cases. An attempt is made later to interpret these opinions in the light of the data supplied by the 1918-19 analyses. The authority for the record quoted is given in square brackets at the close of the sentence or paragraph [See footnote below.]

NORTHERN CIRCLE.

None of the moister forests are free from the borer [R. F. A., 1908-09, p. 52.]

1. *Myitkyina*.

The beehole borer as a serious pest is confined to the Indawgyi valley, being much less abundant in the Namyin and Kaukkwe drainages and scarcely occurring at all in the forests along the Irrawaddy ; in the Taungbalaung Reserve in the Upper Defile the borer is practically absent ; the Kyunsalai plantations in the Nammun Reserve, Indawgyi are badly attacked. Timber from lowlying forest is worse attacked than that from hillsides, possibly influenced by the fact that nearly all the flat forest consists of almost pure teak, while mixed or semi-evergreen forest with scattered teak prevails on hillsides. [D. F. O., Feb. 1914]. The rainfall in the Myitkyina division varies from 76 to 108 inches.

B. B. T. C.=Bombay-Burma Trading Corporation, Limited.

C. F.=Conservator of Forests.

D. F. O.=Divisional Forest Officer.

F. C.=Foucar and Company.

F. Z.=Forest Zoologist.

S. B.=Steel Brothers.

R. F. A.=Report on Forest Administration in Burma.

W. P.=Working Plan.

In 1918 Mr. F. A. Wrigley, in charge of Messrs Steel Brothers' extractions in Indawgyi Range, furnished the Conservator of Forests, Northern Circle, with the following facts regarding the occurrence of the beehole borer, based on 21,000 girdlings.

Name of forest coupe.	Type of forest.	Incidence of borer.	REMARKS.
Nanyinka, Coupe I. 1500-1600 girdlings.	(a) Practically pure teak occupying grassy flats round Lake Indawgyi.	(a) Free from bee-hole.	(a) Undergrowth of heavy Kaing grass, subject to violent annual fires.
	(b) Moist ever-green forest containing scattered teak on flattish ground.	(b) Very badly bee-holed.	(b) Ever-green under growth, so damp that leeches exist in it perennially; never subject to fire.
	(c) As for (b) but on hill slopes.	(c) The incidence of the bee-hole varies directly with the elevation, i.e., the higher the elevation, the less the bee-hole attack.	(c) Owing to damp mists over the lake, practically incombustible on lower slopes. Bamboos on higher slopes.
Coupe II. Unclassed forest west of lake, 3,000 girdlings.	Open kaing forest containing clumps of pure teak, and much scattered cultivation.	Free from bee-hole.	Subject to annual fires.
Coupe III. 2,000 girdlings.	Contains the 3 classes described in coupe I.	Similar to coupe I	
Coupe IX. Dagwin Chaung, 200 girdlings.	Practically pure teak	Free from bee-hole.	The trees are mature and the area was fire protected for only about 10 years.

N.B.—“Free from bee-hole” means that no single log is classified by the firm as a bee-holed log.

Mr. Wrigley emphasises the fact that, in areas in which patches of ever-green forest adjoin patches of pure teak growing in heavy kaing grass, the beehole borer is invariably confined to the teak in the ever-green, while the pure clumps are immune. [C. F., N. C., 1919.]

The Report on Forest Administration in Burma for 1911-12, states p. 27, para. 88, that the beehole borer (*Duomitus ceramicus*) appeared in the 5-year old plantations of Zigyun Reserve, "about half the trees in the plantation were found to have been attacked and these were felled and burnt." A note in the Reserve Journal dated 16th October 1912 states that "hitherto Zigyun teak has appeared quite free from the bee-hole borer, but within the last few months odd trees in the pole stage naturally grown and remote from plantations have been found badly attacked." The writer examined these plantations in April, 1914, and found that the beeholing was not due to *Duomitus ceramicus*, but to previously unknown borers *Phassus signifer* [Hepialidae] and *Haplohammus cervinus* [Lamiidae.]

2. Bhamo.

The borer occurs in teak forests throughout the division and particularly in the Shwegu sub-division on the right bank of the Irrawaddy. Beeholed timber is regularly obtained from the drainage areas of the Kaukkwe (especially from the Nansonti Reserve and adjacent forests), the Mole (particularly in forests drained by its tributary the Nampaung) and the Mosit (particularly from the Leiksin tributary). As a general rule most damage is met with in trees growing in low-lying evergreen areas, but in the Leiksin, trees growing on hills and ridges are more severely attacked than those found in ravines and small valleys, or in jungles where *Bambusa Oliveriana* predominates. [S. B., Dec., 1913.]

The working plan for Mosit Reserve 1910-11 to 1939-40, p. 6, para. 14, notes that teak plantations near Nampu are badly attacked and suggests that the pest is spreading as poles are more seriously attacked than mature trees.

For details in the observation area established at Okkyi on the Kaukkwe stream, see pp. 71—76.

3. Katha.

The borer is present throughout the division but most abundant in Mohnyin Reserve. Timber growing in moist forests in level or undulating country suffers far more than timber from hill forests, but this may not be due to the locality so much as to the fact that in the low-level forests teak forms a larger proportion of the crop. Beeholing seems to occur anywhere where teak is very numerous, provided the forest is fairly moist, but the drier forests such as Pile and Pyinde, although containing large numbers of teak poles, appear to be comparatively free. In the plantations of Petsut, Nami, and Mohnyin Reserve, and in the Bilumyo regeneration block considerable damage has been done. [D. F. O., Dec. 1913; S. B., Dec. 1913.]

Timber from the Moda hill forests is badly beeholed [F. C., Oct. 1913], and it is noted that while trees of moderate girth show many beeholes on conversion, old trees of very large girth yield timber near the heart of good quality practically free from beeholes [F. C., 1919.]

The Mohnyin Reserve lies on flat ground in the valley-plain of the Nanyin stream at an elevation of 500 ft. with a rainfall of about 70 inches and a temperate climate. The teak forests are rich in mature trees and practically pure with bamboos absent or relatively scarce, but the reproduction is comparatively poor.

For details as to the occurrence of the borer in Quarry Siding Plantation, Mohnyin Reserve, see pp. 60—66, and for conditions in the Bilumyo Regeneration Area see pp. 57—59. The mean annual rainfall of the division is between 56 and 72 inches.

4. *Upper Chindwin.*

The borer is not notoriously abundant, but appears, from an examination of the timber, to be regularly distributed and a permanent resident. The locality cited comprises the hill ranges lying between the Chindwin river above Kindat, and the Kabaw valley (Yu River); the elevation varies from about 500 to 3,000 feet; the forest is mainly deciduous, with occasional patches of ever-green; teak occurs up to about 1,500 feet and forms 5 per cent. to 10 per cent. of the growing stock. [D. F. O., Oct. 1913]. The rainfall is about 70-75 inches.

Timber is very noticeably affected in the Kampat Reserve, Mawku working circle, and in the Ahlaw Reserve, Ahlaw working circle; the borer is generally prevalent in all forests west of the Chindwin and is very seldom encountered to the east of the river. [B. B. T. C., Dec. 1913.]

5. *Mu.*

The divisional officer and principal teak lessees agree that the borer is rarely found, but one observer states that large logs are generally, free from beeholes while small poles are invariably damaged [D. F. O., Nov. 1913.] More recently the Bombay-Burma Trading Corporation, state that no signs of the borer have been found, either in the vicinity of the Pyaungthwe and Yabin Reserves, which are dry teak forests on the east slopes of the Mu-Chindwin water-shed, or in the moister Budaung and Thaw reserves on the Mu-Irrawaddy water-shed in the east of the division. [D. F. O., Aug. 1919.]

6. *Myittha.*

The borer appears to be spread over all teak-bearing forests, and is particularly abundant in the Matu Reserve in the drainage of the

Paluzawa stream; in the Kyaukka Reserve timber is comparatively free from beeholes, in the Bon Reserve the borer is more abundant and in the Chin Hills it is fairly common. The borer is not found regularly throughout the forests but sporadically in patches. In the Taungdwin drainage the pest is comparatively rare, but is more plentiful in low-lying and sheltered localities than in higher and more hilly country.

The Bombay-Burma Trading Corporation point out that, while timber is very badly beeholed in the region of the north branch of the Paluzawa stream, the forests of the neighbouring Nanzalein stream are hardly attacked by the borer.

The forests of the Matu, Bon, Kyaukka and Taungdwin Reserves are of the dry mixed type in which *Xylia dolabriformis* and *Terminalia tomentosa* are the predominant associates of teak; the country is hilly with north and south ridges between 2,000 and 3,000 feet in elevation. [D. F. O., Jan. 1914.]

7. Lower Chindwin.

A regularly occurring pest. [D. F. O., Oct. 1913.]

The presence of the borer is exceptional. Instances of attack were noticed in timber extracted from the lower slopes of compartments 36—47, Pantalon Reserve, Pweton drainage [D. F. O., Sept. 1919.] The forests mentioned are moist deciduous, fire protected to 1911 and situated in highly dissected hills (1,000 feet), with a rainfall of about 50." Teak reproduction is fairly good.

SOUTHERN CIRCLE.

8. Yaw.

The beehole borer is nowhere very plentiful, but is found to a certain extent in most teak forests, but most plentifully in the Kyaw Reserve, Pauk Range, and in the North and South Gangaw Working Circles, Gangaw sub-division. Beeholed timber is not often found in the Yaw Working Circle. In the Kyaw Reserve it is most plentiful in the hilly mixed teak forests, where the soil is dry and sandy and well-drained. In the Gangaw Working Circle, the timber lessees state that they find it most plentifully on the lower slopes of hills and in the denser forests. [D. F. O., Sept. 1919.] The Working Plans [1916 and 1917] for these reserves make no reference to the borer, and the Divisional Officer observed in 1905 that the borer did not occur in Gangaw sub-division.

The forests of the upper mixed type occur in hill country \pm 1,500 feet with a rainfall of 50-60 inches.

9. *Meiktila.*

Presumed to be absent, except from the Popa forests [D. F. O., Dec. 1919].

10. *Ruby Mines.*

The borer occurs in the division but is usually not a serious pest. [D. F. O., 1913 and 1919] Timber in the Nanme Working Circle (in an isolated hill-tract forming the Irrawaddy-lower Shweli watershed) is badly beeholed, particularly in the drainage of the Pawaing stream a tributary of the Nanme creek that flows into the Shweli [D. F. O., Dec. 1913.] The teak-bearing forest is of the very moist mixed type with dense bamboo and ever-green under-growth.

In the Hintha, Ondok and Kyauktaung Reserves "the borer is not reported to be very prevalent" [Working-Plan for the Hintha Working, Circle 1908-09 to 1937-38.] The forests are drier than those previously mentioned and situated in less steep and less elevated hills. Mr. W. G. Moore, of the Bombay-Burma Trading Corporation, states (1919) "the Hintha Reserve in the Shweli is very dry, is regularly burnt very badly in parts, and is more subject to the beehole borer than any other forest in the Ruby Mines." The borer has not been recorded from the Hmaingdaing and Tauttakugyi Reserves in the drainage of the Tagaung stream, a tributary of the Irrawaddy; the forests are considerably drier and annually burnt (rainfall 45 inches) with teak on flat land along the streams.

In the Working Plan, 1911-12 to 1930-31 for the Wapyudaung forests, which lie in a narrow belt on the west slope of the watershed between the Irrawaddy and the south-west branch of the Shweli river, and are of the dry mixed deciduous type (rainfall 30-45 inches) it is stated that "insects do damage," but no reference is made to the occurrence of the beehole borer.

A log from the Shweli Forests, 27' by 6½' girth, examined by the writer in the Rangoon Mills of the B. B. T. C. showed 421 beeholes exposed on the faces of planks and beams [*vide*, p. 100.]

11. *Mandalay.*

The presence of the borer in the Madaya Range was noticed by the D. F. O., in 1912 and again in 1919, "in all fire-protected teak plantations. I did not notice any in the natural teak in the unprotected parts." The Madaya valley is elevated and hilly with a rainfall of 60-95 inches; the teak forest is of the moist mixed type.

11(a) Northern Shan States.*

The working-plan for the Bawgyo Working Circle 1914-15 to 1943-44 notes that "Messrs. the B. B. T. Co., Ltd., report that almost all trees (including even saplings) are attacked by larvæ.....of *Duomitus ceramicus*. The writer has seen logs from these reserves both at Rangoon and in the forest; the percentage showing "beeholes" is undoubtedly high; and even of those which in the round show little sign of attack many are found in the saw-mill to be riddled with larval passages. Attacks by the larvæ of this moth are usual wherever the percentage of teak is unusually high; but in these forests the pest is probably aggravated as a result of the illusage to which the teak has been subjected." "The attacks of this insect seem to have been worst in the reserves south of Hsipaw," [i.e., Tonglong, Pangsha, Tunpye, and Tawngkhke] while as far as present appearances go the logs extracted from the Namtu reserve are free from it. If this turns out to be the case, it is possible that protection and the removal of unsound trees may help to eradicate the pest as the area where it is worst, viz., the Tonglong has received the worst treatment in the past while the Namtu has suffered least."

The B. B. T. C. [Dec., 1913] recorded the presence of the borer in abundance to the east, north-east and south-east of Hsipaw, [i.e., Namtu and Namma Reserves] near Bawgyo, in the Baw Reserve, and in a slight degree in forests of low elevation south-east of Maymyo.

The Namma forest is cited as "a typical borer infested area." It is further remarked that "the type of forest most attacked by the borer appears to be deciduous forest areas with a rocky laterite or sandy soil and it is also interesting that in forests mostly attacked by the borer the undergrowth is generally long grass." In 1919, Mr. W. C. Moore, B. B. T. C., writes "of all the forests I have worked in during my 30 years in Burma, the Pyaungshu Forest is far and away the worst as regards the bee-hole borer. I was in the Pyaungshu Forest from 1899-1907, and during the whole of that period, the areas above mentioned were swept annually by forest fires."

In 1914, the Forest Zoologist worked through natural forest in the Namtu and Namyan valleys in the neighbourhood of Hsipaw, and found the borer relatively abundant. A sample plot taken in pure evenaged teak annually fired and near villages, in the Namma Reserve gave the following data:—

(a) Trees without external signs of attack	. 54 per cent.
(b) Trees with old open holes or scars	. 22 ..
(c) Trees with fresh holes of the current season	24 ..

From one of the trees in this plot 62 moths emerged in April-May, 1914.

The forests occupy part of a limestone and laterite plateau of low hills and broad valleys, 1,500—2,800 feet elevation, with a rainfall of about 55 inches; they have been heavily worked and ya-cultivated and contain little mature teak except in the inaccessible ridges, but there has been profuse natural regeneration with the production of well-stocked, nearly evenaged pole woods and thickets.

It is not improbable that the latter is one reason for the relatively high abundance of the borer in the Pyaungshu and Hsipaw teak forests. The progressive reduction of the mature trees would concentrate the borer attack on the ungirdled trees, while the simultaneous provision of young teak growth would maintain and increase the borer incidence.

12. *Southern Shan States.*

No information available, except for forests near the Pyaungshu, e.g., N. Lawksawk, where conditions are similar (W. A. Robertson).

13. *Pyinmana.*

In the Yonbin and Palwe Reserves to the west of the river Sittang the beehole borer is not at all common. The percentage of logs showing one beehole at the ends or the sides is estimated at less than 5 per cent. In the country to the east of the Sittang drained by the Pane and Mazi streams the percentage is very much higher; the borer is generally distributed, but pockets of teak may occur at any elevation between 400 and 2,200 feet in which the incidence is extremely high. It is noted that the attack of the borer in old trees now standing in paddy fields, remnants of forest that existed previous to the extension of cultivation, is much more numerous than in paddy-field teak of recent origin. [B. B. T. C., Dec., 1913].

In the Mayoban drainage of the Yezin Reserve north-west of Pyinmana bored timber is plentiful [C. F., S. C., Dec., 1913].

The various working-plans agree that the damage due to insects is inconsiderable and requires no special protective measure. For details of the occurrence of the borer in sample plots in Yanaungmyin and Kaing Reserves, see pp. 76—88.

14. *Minbu.*

The Taungdwingyi Forests (Pegu Yoma—Magwe District) do not contain beeholed teak in appreciable quantities; the teak is isolated in comparatively small blocks. In the Mon and Salin drainages (Irrawaddy

west bank) no more than a very slight occurrence can be traced, but the forests are almost unexplored (D. F. O., Dec. 1919).

PEGU CIRCLE.

15. *Thayetmyo.*

Present in the East Yoma Reserve [D. F. O., Sept., 1913] in teak forest of the upper mixed type at about 1,500 feet; rainfall possibly 45 inches. The proportion of beeholed logs from this division recorded at the Rangoon dépôt is 8 per cent.

16. *Prome.*

Recorded from various reserves, but not abundantly. The output of beeholed logs is considered to be higher than from Thayetmyo division.

17. *Zigon.*

The beehole borer was noted in plantations in Zigon Division, where fortunately the pest is rare. [R. F. A., 1908-09 p. 8., para 41]. In 1919 the D. F. O. noticed beeholed trees to a greater or less degree in all plantations, but considered that none of the natural teak suffers appreciably.

18. *Tharrawaddy.*

Present in all reserves on the west slopes of the Pegu Yoma, Minhla, Mokka, Kadinbilin, Konbilin, Thonze, but is not so abundant as in some of the Upper Burma forests [D. F. O., Nov., 1913.] None of the working-plans for these reserves mentions the occurrence of the borer.

Stebbing [1905] notes that "Bee-holes in teak in the Tharrawaddy Division are said to be by no means common" and records finding examples in plantations in Kadinbilin Reserve.

Present in plantations of the Thonze Reserve [F. R. O., Jan., 1915]. Present in Konbilin Reserve in natural forests and plantations [F. Z., 1917] (for details of the incidence in plantations near Hmyachaung, Konbilin, see pp. 95-97).

The forests in the above-mentioned reserves on the west slopes of the Yomas are of the upper mixed type both moist and dry with a rainfall of about 80 inches.

19. *Rangoon.*

With regard to Okkan Reserve it is stated [D. F. O., Nov., 1913 and F. C. Oct., 1913] that the borer is very abundant. "Only 10 per cent.

of the timber extracted is entirely free from bee-holes ; of the remaining 90 per cent. about $22\frac{1}{2}$ per cent. has an occasional beehole which does not depreciate the value of the timber in any way ; about another $22\frac{1}{2}$ per cent. is bee-holed to an extent to cause the timber to fall into the II class (say 4-12 holes per square) and the balance of 45 per cent. is seriously damaged." In 1919 Mr. Nuding, Manager, Messrs. Foucar & Co., notes that "the borer seems to be fairly evenly distributed over the whole of Okkan Reserve, but apparently is not so bad as in some forests, such as the Kalon and Moda areas, Katha district. The beehole, in nearly all cases noticed, is in the top log cut from the tree and in the top end of that log. The percentage of bee-hole logs in one area was estimated at 35 per cent. The area is all dry forest more or less open and it has not been fire-traced for a number of years. In another area, Compart. No. 20 [Hlaing Yoma Forest] which is a fairly wet one the beeholes found were comparatively few, whilst in Compart. 21, which is again dry forest, about 25 per cent. of the logs have bee-holes in them, but in this Compartment a number of bee-holes were found in the bottom logs, as well as in the top ones. Both Compartments 20 and 21 were fire-traced until about 5 years ago, but since then these compartments have been burnt over each year."

Okkan Reserve occupies low and generally not steep hills at the southern end of the Pegu Yomas and is the southernmost of the large teak reserves in Burma ; the rainfall is high, probably about 100 inches per annum.

20. Pegu.

Timber from all parts of the South Zamayi Reserve is reported by lessees to be badly beeholed (F. C., 1913). The Report on Forest Administration for 1910-11 states p. 8, para. 29, that "some damage was done in one of the teak plantations in the South Zamayi Reserve. This is not serious at present and is confined to dominated or suppressed trees which would be removed when thinnings were made." The Report for 1912-13 records p. 13, para. 37, serious damage by *Duomitus ceramicus* in Pegu Division.

In 1919 the Divisional Forest Officer notes that he "did not see anything like the number of trees attacked inside the fire-protected areas [under 10 years] as were seen in the fairly old plantations that have not been fire-protected."

South Zamayi reserve is situated on the south-eastern terminations of the Pegu-Yoma range in hill country below 1,000 feet ; the teak forest is of the upper moist mixed type with a rainfall of about 125 inches.

TENASSERIM CIRCLE.

21. *Shwegyin and Nyaunglebin.*

In 1905 reported by Divisional Forest Officer to be uncommon. Stebbing [1905, p. 12] records the borer from "the Shwegyin plantation on the Salween River." In 1913 the Divisional Forest Officer noted, "this division is not one of those which has regularly yielded bee-hole timber in the past, and on the contrary I think the mature timber at present being extracted by the lessees is almost immune from its attacks.

Nevertheless since the year 1907 every officer inspecting the plantations [to the south of the Yenwe Range] has annually complained bitterly of the damage being done by this pest."

"The small Impatle Reserve is practically free from the teak-borer, but in the Upper and Lower Kanyin Myoung Reserves, to the south of the Impatle the teak is very bee-hole" [F. C., Oct., 1913]. These 3 reserves lie in the plains between hill forests on the west and paddy plains on the east. The Impatle is swampy.

With regard to the Nyaunglebin Working Circle the Divisional Forest Officer notes in 1919 "The timber firms say that the presence of the borer is very irregular; for instance teak trees in the outer foot-hills, Aingdon-Kun compartments, north of the Tonkan Chaung, are very badly bee-holed, where as those in the upper and middle reaches of the Kunchaung are very much less so; and similar differences occur over most of the hill forests. The outer foot-hill teak forests of the Aingdon-Kun Reserve burn over early in the season from spread of fire from paddy fields, whereas the middle Kun forests burn over later and consequently more fiercely." The above mentioned forests occupy low hills, 500-1,000 feet, extending in a south-easterly direction from the crest of the Pegu Yomas, rainfall ± 100 .

With reference to planted teak the Divisional Forest Officer, Nyaunglebin, notes that in the Mogaung plantations which have been fire-protected since their foundation up to 1919, "the bee-hole borer is extraordinarily bad, in fact many parts are ruined by it." The Dodan and Chikku plantations were similarly protected during their early years (and the latter continuously up to 1919), but the borer is not so prevalent as in the Mogaung plantations, the localities being drier throughout than the Mogaung plantations which have considerable evergreen forests in the neighbourhood. The R. F. A. for 1908-09, p. 30, para. 61, notes "the beehole borer is present in large numbers in the plantations at Chikku and that a considerable amount of damage is being done. The pest is spreading to the adjoining reserves, where teak trees of the lower age classes are being attacked."

22. South Toungoo.

All forests west of the river Sittang yield beeholed timber regularly. The percentage of beeholed logs observed during one week's working in Messrs Macgregor & Co.'s Rangoon Mill varied from 12 to 85. The forests concerned are of mixed deciduous type in the Pegu Yoma at an elevation of 300 to 2,000 feet [D. F. O., Nov. 1913]. In 1900-01 badly beeholed timber was extracted from the Pyukun reserve.

With regard to conditions in plantations in Bondaung Reserve, see pp. 92—94.

23. North Toungoo.

Beeholed timber was extracted from the Gwethe Reserve in 1895 [D. F. O., 1905].

Beeholed timber turns up occasionally from any one of the reserves but no reserve can be said to be worse than another in this respect. The Pyonchaung plantations are very full of it [D. F. O., Nov. 1913].

For details as to conditions in the Pyonchaung Reserve see pp. 88—92.

24. West Salween.

Of the Sittang forests, in the Kyundaung Reserve the borer is scarce, but is more plentiful in the Westwundaung Reserve. The first area is hilly and the second is dry plains forest [F. C., Oct., 1913].

Messrs T. D. Findlay & Son, Limited, state in 1919. "The West Salween is perhaps freer than the other forests we work, though the Mewaing is bad." The Report on the Forest Administration in Burma for 1910-11 states p. 30, para. 42, that "a bee-hole borer, evidently *Duomitus ceramicus*, is reported as affecting plantations in the Mewaing Reserve" while the report for the following year 1911-12, p. 26, para. 86, states that the borer "has not re-appeared in the Mewaing Reserve." Stebbing [1905, p. 15] states that the Sinswe Reserve is badly infested.

In October, 1919, the D. F. O. mentioned 14 reserves in which the borer is believed to be present. Some are on flattish alluvial soil and some in distinctly hilly country; all were fire-protected until a few years ago.

The rainfall in this district is \pm 150 inches.

25. Thaungyin.

The Divisional Forest Officer in 1905 stated that forests on poor soil and those annually burnt over are said to contain more beeholed timber than others; and that timber from the Siamese side is more beeholed than that from the British side.

Messrs Steel Brothers stated in 1913 that the borer is regular in this division and possibly to a greater extent in government plantations than elsewhere. Considerable damage to teak plantations is recorded in the Report on Forest Administration in Burma for 1909-10, p. 30, para. 43, and Report on Forest Administration for 1911-12, p. 26, para 86.

The rainfall in this district is 150—200 inches. Early references to the occurrence of the borer are given on p. 5.

26. Ataran and 27. South Tenasserim.

There is general agreement that the borer is absent. The rainfall is \pm 200 inches.

SUMMARY.

The geographical distribution of the borer in Burma seems to be coincident with the distribution of the teak ; general opinion considers it to be most abundant in the more richly stocked teak-bearing forests, in patches of pure teak growth and in certain types of moist forest. It occurs in localities with rainfall between 50 and 150 inches and with elevations of 250 to 2,000 feet, but decreases in abundance towards the dry zone and towards regions of high elevation and rainfall, *i.e.* towards the boundaries of the habitat of teak.

Mr A. Rodger considers that the borer is worst in the following forests : Mohnyin, Katha, Hsipaw State, Mawmai State at 2,000,' West of the Upper Chindwin and Pyinmana East Bank Forests.

JAVA.

The attack of *Duomitus ceramicus* on teak in Java was recorded first in 1899 (van Braam, 1899) and again from 1902 onwards by subsequent writers. (Salverda, 1902 ; Sorauer, 1908 ; Konigsberger, 1908, 1915). Milward (1915, p. 3) states that "teak in Java suffers *very little* from defoliation or beehole borers." Beekman (1919, p. 5 *et seq*) says "In the practical utilisation of teak timber in the Dutch East Indies very little attention has so far been paid to beeholes ; the value of the timber on the market is not depreciated for this reasonPractically the injury is at present of little importance, but this may however quickly change when the timber trade begins to pay more attention to it," [p. 6]. He further notes that the borer is fairly commonly distributed in Java, but cannot be numerous in natural forest since trees up to 100 years and over show only a few beeholes per tree. In plantations on the

other hand the borer appears at a very early stage (attack on one year-old trees is recorded) and may occur locally in large numbers. "The increased incidence is always very localised; in one and the same year the pest may be abundant in one place, and totally absent in another, whilst in the following year it may be just the reverse Even a local increase is usually narrowly limited. Thus, within extensive plantations, 1 or $\frac{1}{2}$ hectare may be badly attacked, while the remainder is immune," [p. 13]. Commenting on the annual incidence data for Burma supplied by the writer Beekman notes that these, if applicable to Java as well, would cause some anxiety (indien zijook voor Java zouden gelden, den schrik om het hart zouden doen slaan).

Teak occurs in Java on undulating ground up to about 2,000 feet in remarkably rich crops. The purity of the species varies from about 50 to 99 per cent.; the natural regeneration is excellent and bamboos are absent; the rainfall is over 70 inches. The forests are treated by clear-felling and artificial or natural regeneration including coppice or a combination of both (Milward).

The conditions are such as are, at present, considered in Burma to characterise a bad beehole area. It appears not improbable that the relative abundance of the borer in moist pure forests is more a matter of opinion than of fact.

PART II.

Description of the stages of the insect.

(Described from specimens collected in various localities in Burma, 1914—19.)

1. THE MOTH.

[Plate iii, fig. 4.]

General description. HEAD. Pale grizzled brown ; antennæ brownish, simple, threadlike in the female, bipectinate basally in the male.

THORAX. Above and at the sides grayish to pure white, with a patch of black clubbed scales behind the insertion of the hind wings (meta-thorax), and sometimes with a black longitudinal line or band on the upper (dorsal) surface ; underside with brownish-black hairs. Legs long and robust ; tarsi with sharp bifid claws.

ABDOMEN. Relatively long and heavy, pale brown, more or less suffused with black especially at the sides (excluding the last two segments) ; a black median longitudinal line ventrally and sometimes also dorsally, but more faintly marked ; male with a pair of black tufts at the end of the abdomen ; female with a telescopic ovipositor.

WINGS.—*Forewing*, long, narrow, pale brown with white scaling and variable black-patterning ; the black colour occurs mainly as small transverse spots along the costa, longitudinal lines or streaks near the centre of the wing, and between the veins on the outer and lower borders in irregularly marbled patches ; near the outer angle is a fairly conspicuous white patch with faint dark markings, and margined with black, above and behind, but passing into the general marbling in front. *Hind wing*, shorter and broader, more or less triangular, fuscous, marbled with black and white spots. Underside of both wings with similar, less distinctly marked patterns and darker coloration.

Length.—Female 40 to 80 mm. ; male 40 to 60 mm.

Wing span.—Female 80 to 160 mm. ; male 80 to 100 mm. [Beekman, 1919, p]. 9). The average size of the Burma specimens is about 100 mm.=4 inches.

The ground colour and markings are very variable but there is a general cryptic resemblance to teak bark. Plate iii, fig. 4 shows a moth in a typical resting attitude on a teak tree. In living specimens the colour pattern is apparently composed of black and white scales only, but in dead or rubbed specimens a pale brown colour pervades,

due chiefly to the exudation of oil from the body, which spreads to the wings. Butler's [1886, p. 29] and Hampson's [1892, p. 307] technical descriptions were apparently made from greasy specimens. The illustration of *D. ligneus*, Butler in Ill. Het., vi, plate 108, fig. 3 is of an exceptionally dark individual with a prevalent pinkish-brown ground colour. Beekman [1919, p. 9] gives a detailed description of Java specimens, which seem to be darker or browner than the Burma race.

2. THE EGG.

Unfertilized eggs are sulphur-yellow cylinders with rounded ends, about $\frac{1}{4}$ th of an inch long, and are laid in strings or clusters of a hundred or more stuck together with a cement soluble in water. Beekman [1919, p. 10] describes the egg as follows:—Yellow or yellowish white, soft with a tough skin, non-transparent but slightly translucent, short cylindrical, with rounded ends $\pm \frac{3}{4}$ mm. long, and about half as much in diameter,—but does not definitely state that they are fertile eggs.

3. THE LARVA.

[Plate i, figs. 1—10; Plate iii, figs. 1, 2].

General description. The caterpillar is rather robustly built, cylindrical, tapering slightly at both ends, smooth, shining, hairless except for scattered light brown hairs (the setae discussed in the technical description). The head is prominent, reddish to chestnut brown in colour; with black jaws, the thorax light brown, the hind portion with a rough surface formed by numerous backwardly directed teeth; the body is marked with alternate transverse pink and white bands and prominent brown oval spots (spiracles) on each segment. The coloured illustrations on plate iii, figs. 1, 2 are sufficient to identify the caterpillar and it also the only pink and white striped caterpillar with a rough shield on the thorax, that is known to bore into teak.

Length up to $2\frac{1}{2}$ inches.

MATURE LARVA.

[Plate 1, figs. 1—10].

Technical description.* *Form*, robust, cylindrical, slightly flattened ventrally, prothorax strongly declivous, thoracic and last 3 abdominal segments tapering.

Colour.—White: head reddish to chestnut brown with mandibles and condyles black, and labium pale testaceous, edged with chestnut;

* Terminology according to Fracker, 1915.

prothorax chitinised above and dorsolaterally, light brown ; abdominal segments 1-9 and sometimes also thoracic segments I and II with anterior transverse pink bands ; the bands are usually about half the width of the segment, but may be broader ; the colour varies from crimson lake to pale pink, and may disappear entirely from the median segments ; white individuals occur in which only the thorax and 9th segment are coloured.

HEAD. [Plate i, figs. 1 & 2]. The arrangement of the setae has not been specially studied ; the figures show those present and their relative positions. Ocelli I, II, III in a broad based triangle, IV caudad of the line II, III, VI, and V caudo-ventrad of VI. The mouth parts have not been separately studied.

THORAX. *Prothoracic Shield*. [Plate i, figs. 3 & 4] longer than broad, anterior margin transverse, sides parallel, with two more or less separate deltoid extensions laterally, posterior margin broadly rounded ; anteriorly strongly declivous, smooth, shining, posteriorly slightly depressed and strongly asperate. The asperities of the posterior area consist of (a) an arcuate line of about 25 sharp teeth raised at 45° and directed backwards, with a row of 4-5 of the largest teeth in advance of the rest, (b) an elliptical area of 4 or 5 ill-defined rows of slightly smaller teeth and (c) a posterior zone of numerous minute teeth in which the linear arrangement is lost. The large teeth are interspersed to some extent with small, and all become minute and effaced at the margins of the shield.

Spiracles, [Plate i, figs. 5—7] large, oval, sub-equal except thoracic and 1st abdominal, which are slightly larger, margins raised, golden-brown with dark depressed centres ; spiracles on segment 8 one-third larger, subdorsal ; thoracic segments II and III with a dark spot in the triangle formed by setae theta, kappa and eta ; these spots represent, presumably, the scars of eliminated thoracic spiracles.

Prothoracic legs, obconical, 3 terminal joints chitinised, with a single claw.

Prolegs on 3, 4, 5, 6 and 10 ; ventral *crotchets* [Plate i, figs. 8] in a complete uniserial ring, pearshaped with the apex mesad, biordinal, the shorter crotchets on an average more than half the length of the longer ; anal crotchets in a transverse band.

Arrangement of the Body Setae.

[Plate i, fig. 10.]

PROTHORAX.—(fig. 10, T. I) alpha, gamma and eta equidistant, in one line on anterior margin of thoracic shield ; alpha considerably

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Description of Plate I.

DETAILS OF LARVAL ANATOMY, DUOMITUS CERAMICUS, Wlk.

- Fig. 1. Head-capsule, mature larva, dorsal view, X 11.
 „ 2. Head-capsule, mature larva, lateral view, X 11.
 „ 3. Prothoracic shield, mature larva, dorsal view, X 6.
 „ 4. Prothoracic shield, 2nd instar, dorsal view, X 15
 „ 5. Spiracle, prothoracic, 2nd instar larva, X 180.
 „ 6. Spiracle, 3rd abdominal, 2nd instar larva, X 180.
 „ 7. Spiracle, 8th abdominal, 2nd instar larva, X 180.
 „ 8. Crotchets of abdominal proleg, mature larva, X 22.
 „ 9. Crotchets of abdominal proleg, 2nd instar larva, X 180.
 „ 10. Setal diagram, mature larva.

T I=pro-thoracic segment.

T II and III=meso-and meta-thoracic segments.

A III=3rd abdominal segment.

A VIII=8th abdominal segment.

A IX=9th abdominal segment.

A X=anal segment.

α =alpha.

θ =theta.

β =beta.

κ =kappa.

γ =gamma.

κ =kappa group.

δ =delta.

μ =mu.

ϵ =epsilon.

π =pi.

η =eta.

ρ =rho.

σ =sigma.

[illegible]

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laterad of the dorsomesal line, the mid-point of alpha and gamma opposite to delta; beta close to dorsomeson at the corners of the advanced row of 4-5 teeth; delta ventrocaudad of beta, adjacent to the terminal lateral tooth of the anterior line of teeth; rho near to and level with epsilon, both of which setae occur on the less strongly chitinised lateral extension of the shield; Kappa group trisetose, with theta, kappa and eta arranged in a triangle on 3 separate pinacula, cephalad of the spiracle, the middle seta the longest and ventrad, the caudal seta the shortest; Pi group of two non-adjacent setae.

MESO-AND METATHORAX.—(fig. 10, T. II & III) alpha and beta dorsal on one pinaculum, alpha mesad of beta; epsilon and rho subdorsal on one pinaculum; theta caudad and slightly dorsad of kappa; eta ventrad of and equidistant from kappa; (the spiracular scar lies within the triangle formed by these 3 setae); Pi unisetose.

ABDOMINAL SEGMENTS. I—VII—(fig. 10, A. III) alpha nearer to the dorsomeson than beta; on segment 1 the distance apart of the beta setae is about 3-5ths that of the alpha setae, but this decreases gradually in the posterior direction, until on segment 8 the relative distances apart of the alpha and the beta setae are sub-equal; traces of a minute seta on the anterior segmental margin cephalad of beta (hidden in the retracted body) probably represent epsilon; rho suprspiracular, pinaculum prominent; cephalo—dorsad of the spiracle is a minute seta, visible in middle-sized larvae, but worn off in mature larvae, which I am unable to homologise, and unable to detect with certainty on segment 8; kappa and eta adjacent, on one pinaculum, subspiracular; mu on a longitudinal fold behind the middle of the segment, in a line with beta; Pi group trisetose, triangular, laterocephalad of the proleg; sigma mesocephalad of the proleg.

VIII.—[fig. 10, A. VIII] alpha and beta setae subquadrate; epsilon as in segments I—VII; rho cephalad of the spiracle owing to the elevation of the latter; kappa-eta as in segments I—VII; mu ventrad of them; Pi bisetose.

IX.—[fig. 10, A. IX] beta setae closer together than alpha setae; epsilon as in previous segments, dorsocephalad of alpha; rho kappa, eta, mu and pi (unisetose) in one line on posterior margin.

X.—[fig. 10, A. X] dorsal area with 3 marginal and 1 submarginal pairs of setae, fairly strongly chitinised and provided with one or more pairs of small denticles near the posterior margin; ventral area with about 5 setae grouped on one pinaculum and 5 more disposed singly.*

* Stebbing [1905, p. 10] describes the caterpillar as "consisting of a head and twelve segments the 12th or last segment being much smaller than the rest" but his artist correctly figures it with 13 segments, [Z c., Plate i, figs. aa' and bb'].

Early Instars.

Sufficient material is not available to determine the normal number and the characters of each instar. Head measurements of larvae of various sizes are given on page 44 and the principal differences are summarised below.

SETAL ARRANGEMENT.—In the smallest larvae collected, length 6.0 mm., there is essentially no difference in the setal arrangement. Mu is present on the abdominal segments and theta on the thoracic segments, (and therefore according to Fracker the instar represented is subsequent to the first moult); epsilon is also present as in the mature larva, but this seta as occasionally some of the pi and kappa groups, is extremely minute, and is scarcely visible at magnifications below 100.

CROCHETS.—[Plate i, fig. 9]. In the smallest larvae (? second instar) the crotchets are few in number and distinctly uniordinal; in later stages shorter alternate crotchets appear at the sides of the planta but completely biordinal crotchets are not found until the last stages.

SPIRACLES.—[Plate i, figs. 5, 6 and 7]. There is very considerable change in the relative sizes of the spiracles. In the (?) second instar the spiracles on segment 8 [fig. 7] are very large, oval or deltoid, and more than twice as long as the prothoracic spiracle; the abdominal [fig. 6] spiracles are minute, sub-circular, and about $\frac{1}{3}$ the diameter of the prothoracic spiracle [fig. 5].* In later stages the relative size of the abdominal spiracles increases, until they are sub-equal with the prothoracic spiracle, and are oval in outline. The size of the 8th abdominal spiracles decreases until they are about $1\frac{1}{4}$ times the prothoracic spiracles.

PROTHORACIC SHIELD.—[Plate i, fig. 4]. The design of the posterior area of the shield remains fairly constant; the earliest stage observed shows four teeth advanced between the beta setae, 2 large+1 small in the lateral regions of the first row of teeth, and 8 to 10 teeth in the second row. Later instars show a progressive increase in the number of teeth in the lateral regions of the first and third rows and in the posterior zone. [The arrangement of teeth on the pronotal shield is probably not a specific character: Stebbing's figure of the larva of *Duomitus leuconotus* shows a similar arrangement and larvae of *Zeuzera* spp. show a pattern of the same type].

* In mounted skins the abdominal spiracles are circular and those on segment 8 deltoid, but in spirit specimens all spiracles appear oval in outline as illustrated.

4. THE PUPA.

[Plates ii, iii].

Technical description.* *Form* elongate, cylindrical, heavily chitinised, smooth, shining, appendages fixed [*vide* Plate ii, figs. 1—6].

Colour yellow and light brown when immature, chestnut brown with the thickened portions (frontal process, facial spines, toothed flanges, spiracles, cremaster, etc.), black when mature [*vide* Plate iii, fig. 3].

HEAD.—Epicranial suture (es) distinct, transverse, completely separating head from prothorax. *Front* produced, in its anterior area, into a massive *frontal process* (fp) which rises abruptly in the facial (mesal) plane from between the eyes; ventrally the process terminates against the fronto-clypeal suture in a sharp transverse triangular tooth directed downwards, and slightly excavate in front; it then continues cephalad in a narrow impressed transversely striate strip with raised sub-parallel margins, until it culminates abruptly in an acuminate tip directed downwards and forwards; laterally the process is coarsely rugose, with a deep constriction at the level of the vertex, beyond which it swells out to the anterior margins; anteriorly, *i.e.*, in the dorsoventral plane, the process is obliquely truncate, and longitudinally incised from the acuminate tip, the cleft deepening backwards to the vertex; the incision is bifid for a short distance anteriorly and the lateral lobes produced by it are also longitudinally furrowed; the relative dimensions of the frontal process are shown in [Plate ii, figs. 3 and 4].

Genae indistinct. *Clypeus*, (cl) the anterior boundary is probably represented by the transverse tooth at the base of the frontal process; the lateral margins are marked within by invaginations of the chitin.

Labrum (lb) distinctly margined laterally and distally, but not separable from clypeus. *Mandibles* (md) small, raised, minutely tuberculate bosses at caudo-lateral angles of labrum. *Eyepieces*, glazed eyepiece (ge) and sculptured eyepiece (se) together forming a large prominent convexity, smooth, shining, slightly radially wrinkled along inner lateral edge near frontal process; sculptured eyepiece depressed in a rugose triangular extension between the antennal and 1st leg; (at dehiscence the eyepiece separates along a curved suture, the glazed eyepiece remaining attached to the facepiece and the sculptured eyepiece remaining as an isolated sclerite attached to the prothorax). *Antennae* (a) transversely ribbed, broad and elevated at base, narrowing gradually in ♀ and more abruptly in ♂, extending nearly as far caudad as 1st legs. *Labial palpi* (lp) semi-hastate with, in the middle, a sharp triangular

* Terminology according to Mosher, 1916.

tooth elevated and directed cephalad. *Maxillae* (mx) short, subtriangular with slight extensions at the cephalo-lateral angles, apices rounded and slightly divergent.

THORAX.—*Prothorax* (p) coarsely punctate or rugose except for smooth median area, anterior margin transverse, posterior margin arcuate.

Mesothorax (ms) posterior margin broadly rounded, width nearly 4 times prothorax and 7 times metathorax. *Mesothoracic spiracle* (msp) within a deep slit in the pro-meso-thoracic suture at its lateral extremity.

Metathorax (mt) $\frac{2}{3}$ rd width of 1st abdominal segment. *Legs* 1st coxa elongate with a sharp transverse ridge or tooth near the apices of the maxillae; 1st tibia—tarsus extending slightly beyond apex of 1st coxa; 2nd coxa short, separating the 1st legs; 2nd tibia—tarsus longer than 1st, apices in contact; 3rd coxa invisible; tips of 3rd tarsi visible between apices of forewings. *Wings*, forewings (w_1) extending caudad as far as suture of 3rd and 4th abdominal segments, distal margins in contact; hindwings (w_2) covered except for a narrow strip along the dorso-basal margin.

ABDOMEN.—**FEMALE** with segments 7, 8, 9, and 10 fused together; **MALE** with segments 8, 9 and 10 fused; remaining segments in both sexes moveable.

Flanged plates (fpl) well developed composed of a transverse row of numerous large teeth, directed caudad, concavely excavate below, ribbed and buttressed above; **FEMALE** with one complete row on segment 1, two complete rows on segments 2—7 and one incomplete row on segment 8, the anterior row more strongly developed than the posterior row on the same segment. Segment 1 with one posterior row feebly developed extending almost to wings; segment 2 with posterior row slightly longer than anterior extending nearly to spiracle; segment 3 with anterior row slightly longer than posterior extending nearly to spiracle; segments 4—7 with anterior row extending to ventro-lateral margin of segment, posterior row not reaching the level of spiracle; segment 8 with dorsal part of anterior plate very feebly developed and separate, or entirely absent, lateral part, highly developed, extending to ventro-lateral line. **MALE** with one complete posterior row on segment 1, two complete rows on segments 2—8, segments 1—7 as in female; segment 8 with anterior row complete to ventro-lateral margins, posterior row short dorsal.*

* Beekman [1919, p. 8] describes the pupa faithfully, but from his remarks on the 8th segment in the text and footnote it is probable that his specimens were all males.

Description of Plate II.

В. И. Ленин

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

• *Journal of the American Academy of Child and Adolescent Psychiatry* 1999;38:1031-1038

1. *Staphylococcus aureus* (100%)

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1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

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Department of Health and Human Services

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1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

1. *Chrysomelidae* (Coleoptera): 12 species, including *Chrysomelids* and *Chrysomelids*.

$$\omega_1(t) \cdot \sqrt{t} \rightarrow 0 \text{ as } t \rightarrow \infty$$

Adipose tissue

$$B(\mathbb{C}^n) \cong \pi(Y)$$

Description of Plate II.

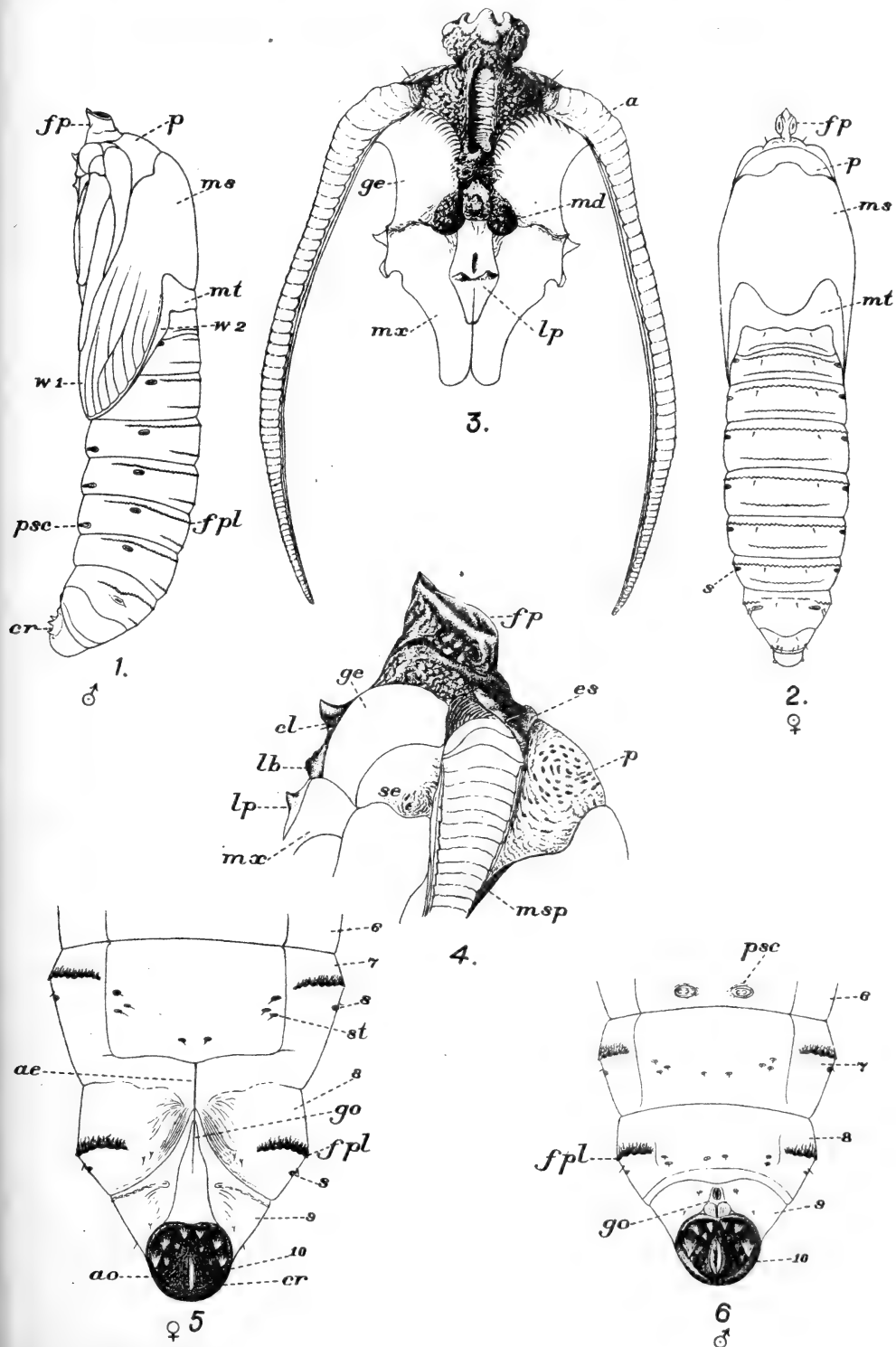
DETAILS OF PUPAL ANATOMY, DUOMITUS CERAMICUS, WLK.

- Fig. 1. Pupa, ♂, lateral view, X. 1½.
,, 2. Pupa, ♀, dorsal view, X. 1½.
,, 3. Face piece after dehiscence ventral view, X. 6.
,, 4. Head, frontal process and prothorax, lateral view, X. 6.
,, 5. Terminal segments of abdomen, ♀, ventral view, X. 3.
,, 6. Terminal segments of abdomen, ♂, ventral view, X. 3.

a = antenna
ac = median carina.
ao = anal opening.
cl = clypeus.
cr = cremaster.
es = epicranial suture.
fp = frontal process
pl = flanged plate.
ge = glazed eyepiece.
go = external genitalia.
lb = labrum.

lp = labial palpi.
md = mandible.
ms = mesothorax.
msp = mesothoracic spiracle.
mt = metathorax.
mx = maxilla.
p = prothorax.
psc = proleg scars.
s = spiracle.
se = sculptured eyepiece.
w₁ = forewing.
w₂ = hindwing.

DUOMITUS CERAMICUS, Wlk. PUPAL DETAILS.



J.B.Singh. del.

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Spiracles (s) on segment 1 concealed, on segment 2 half-concealed by hindwing, on segments 3—7 oval, margins raised, on segment 8 rudimentary. *Proleg scars* (psc) visible on segments 4—6. *Setae* (st) where present, correspond in position and number to the larval setae.

External Genitalia (go); FEMALE. Boundaries between segments 10 and 9, and between 9 and 8, prolonged forwards into the zone of the 8th segment, and closely approximated at the apices. (The sutures are not distinct in the region of the external genitalia, and are lost in the generally wrinkled surface, so that the segmental relations of the anterior and posterior generative openings are doubtful. In nearly all specimens examined the bursa copulatrix and the opening of the oviducts are not separable, but in a few individuals the relative position of each is distinguishable). Together the external reproductive organs appear as a median slit close to the apex of the 10th segment (go) which passes over into a longitudinal ridge flanked by two divergent carinulae; from the bursa copulatrix a fine median carina (ae) extends cephalad beyond the 8th segment to the caudal margin of the 7th, where it terminates in the transverse depression continuous with the dorsal flanged plate; this anterior extension may be straight, but is often sinuous or forked or smoothly interrupted. Viewed from inside the main opening of the bursa copulatrix appears as a laterally compressed funnel-shaped invagination. MALE. Boundaries of segments 10, 9 and 8 distinct and transverse; genital opening (go) on caudal margin of segment 9, consisting of a pair of raised trianguloid or sub-quadrate plates, meeting mesally in a longitudinal furrow; immediately anterior to the genital opening is a rugose or wrinkled area, which appears to be without morphological significance. *Cremaster* (cr) represented by a highly chitinated rugose area on the ventral surface of segment 10, with 10 large conical teeth and a few smaller ones, the points directed backwards. *Anal opening* (ao) longitudinal, margins striate.

Length.—FEMALE 96 mm. to 53 mm.; average (of 20) 68 mm.= 2.72 inches. MALE 76 mm. to 45 mm.; average (of 32) 54 mm.= 2.16 inches.

The above measurements were made mostly from pupal skins which are on the whole longer than the pupae. Beekman [1919, p. 8] gives 7 cm. as the measurement of the pupa.

Duomitus ceramicus agrees generally in its pupal characters with those given by Mosher, for the Cossidae, in the following details:—

“Abdominal segments 3—6 moveable in female and 3—7 in the male” [Mosher, 1916, p. 39]. There is, however, in *ceramicus* distinct movement between segments 2 and 3 and highly probable movement between segments 1 and 2 in both sexes.

"In the ♂ sex the 7th segment has two rows of spines and the succeeding segments one row; in the ♀ the 6th is the last segment with two rows, the remaining caudal segments having but one row" [*l. c.*, p. 40] *Duomitus ceramicus* and Indian species of *Zeuzera*, however, agree in having 2 rows of spines on the 7th segment in both sexes.

Duomitus from its pupal characters, clearly falls into the sub-family Zeuzerinae.

DEHISCENCE.

Separation occurs along the epicranial suture between the vertex and prothorax, completely round the antennae between the sculptured eyepiece and the glazed eyepiece, between the maxillae and the thoracic appendages, so that an anchor-shaped face-piece separates off, consisting of the vertex, frontal process, antennae, glazed eyepieces, clypeus, labrum, labial palpi and maxillae; this remains attached to the pupal case by a narrow strip of skin which extends from behind the mouth parts at the base of the head to the median ventral line of the thorax. The sculptured eyepiece (so termed) remains attached by invaginated skin to the prothorax. Plate ii, fig. 3, shows the face-piece after dehiscence. Splitting also occurs down the median line of the thoracic segments to the 1st abdominal segment, and down the middle ventral line of the thorax, while a distension of the skin occurs between the individual appendages and between the appendages and the thorax; Plate iii, fig. 8, shows the empty pupal skin protruding from the exit hole.

PART III.

Life-History and Habits of the Insect.

As the writer has been able to study the insect in the field only during the months of April, May and June the following account of the life-history is mainly inferred. A summary of the life-cycle will be found on pages 43—46.

OVIPOSITION.

Eggs have not been found by the writer in the field,* although several hundreds of felled and standing teak trees have been carefully examined from crown to stump during the imaginal period. Numerous specimens of eggs of other lepidopterous families, of Rhynchota, Neuroptera and Orthoptera were recovered from teak bark.

Egg-laying by captive females in April, 1914, commenced on the second day after emergence from the pupa and continued steadily until death occurred; from 300 to 600 eggs were deposited by each female in the course of 4—6 days, usually in long moniliform rows on the sides and floor of the cages, but where crevices or holes were available eggs were deposited in hundreds as far as the ovipositor could reach. Villar [1916, p. 513] records similar habits in the case of females bred and caged by him in April, 1916, and notes the commencement of egg-laying 3 days after emergence. Beekman [1919, p. 10] also states that sterile eggs are laid in rows and groups shortly after emergence.

Location of Eggs.—By analogy with the habits of other Cossidae it may be assumed that eggs are laid by the female in cracks, and under scales of bark on the tree-trunk.† Mr. R. Unwin, in his report on the Pyinmana Observation Area (July 1916) expresses the opinion that “eggs are probably laid in crevices as none were found on undergrowth although careful search was made in every way.” Mr. A. R. Villar records in his report on the Shwegu Observation Area (July 1916) that “a very careful search was made for eggs..... all undergrowth and teak shoots and the accessible portions of teak trees being examined, a hand reading-glass being used, but entirely without success.” Beekman [1919, p. 10] is of the opinion that “probably eggs are laid separately with the blunt ovipositor in bark-crevices of living trees.” The

* The eggs taken on teak bark and described in the Forest Zoologist's report for 1914 as *ceramicus* eggs, on the evidence of a pink and white striped embryo, have, after microscopic examination of the setal arrangement, proved to belong to another family.

† Beekman [1919, p. 10] states on the authority of an unpublished note supplied by the writer that an egg-cluster was found on a terminal shoot of a teak seedling, 3 feet above ground. It is now extremely doubtful that these were *ceramicus* eggs.

distribution of early larval attack over the whole bole of the tree, and the very rare occurrence of two larval burrows near each other, may indicate that the eggs are laid singly or in small numbers. In connection with this subject it is worth recording that female moths in cages showed a constant tendency during the first few days of life to climb upwards and remain at rest on reaching a summit; later on this phase was replaced by negative phototropism and a desire to squeeze into dark shelters at a low level. A few moths captured in the open were taken resting on the bark of teak trees; when disturbed they crawled upwards without attempting to fly. In order to determine if eggs were laid on the bark or scattered on the ground Mr. W. C. Rooke tar-banded 50 trees on the 26th April, 1916, near the Observation Area, N. Toungoo at 1½ feet above ground and removed all undergrowth. No signs of boring larvae above the bands were observed until the 23rd May, indicating that eggs were laid on the trunks after the tarring of the trees, or if the incubation period is over 3 weeks that eggs were laid above the tar-bands before their application.

LARVAL HABITS.

THE BARK CHAMBER AND EARLY LARVAL WORK.

[Plate iii, Fig. 5].

The first larval instar is at present unknown (see p. 28); presumably the larva on hatching from the egg bores straight into the bark as the smallest (2nd instar) larvae have been discovered in this position. The initial excavation is confined entirely to the bark; the burrow is at first extended from the point of entrance for about half an inch upwards and downwards in the inner bark and bast. It is then enlarged laterally and carried inwards until the cambium is reached by biting out small recesses, which coalesce into larger embayments and sometimes extend in short tunnels. At this stage the larval burrow is filled with pellets of excrement and fragments of bast wet with sap, and no sign of its presence is visible on the outside except perhaps a thin trickle of sap and a film of black bark-dust. [See Plate iii, fig. 5]. The 2nd stage larva lives for a few days at least in a semi-liquid mass of chewed-up tissue, and the modification of the spiracles at this period is probably correlated with anaerobic conditions. The period may also be one of high mortality, since the number of larvae that develop their galleries to the next stage is comparatively very low.

The larval chamber is enlarged further, and mainly in a longitudinal direction, until its inner wall is formed by a shallow groove in the sapwood

All staff to undergo 41

THE BETHLEHEM BOARD OF TRADE.

Description of Plate III.

THE SEASONAL HISTORY OF DUOMITUS CERAMICUS, Wlk.

THE BEEHOLE BORER OF TEAK.

Fig. 1. Young larva, lateral view.

„ 2. Mature larva, last instar, dorsal view.

„ 3. Pupa, ♂, immature, ventral view.

„ 4. Moth, ♀, in resting attitude on bark.

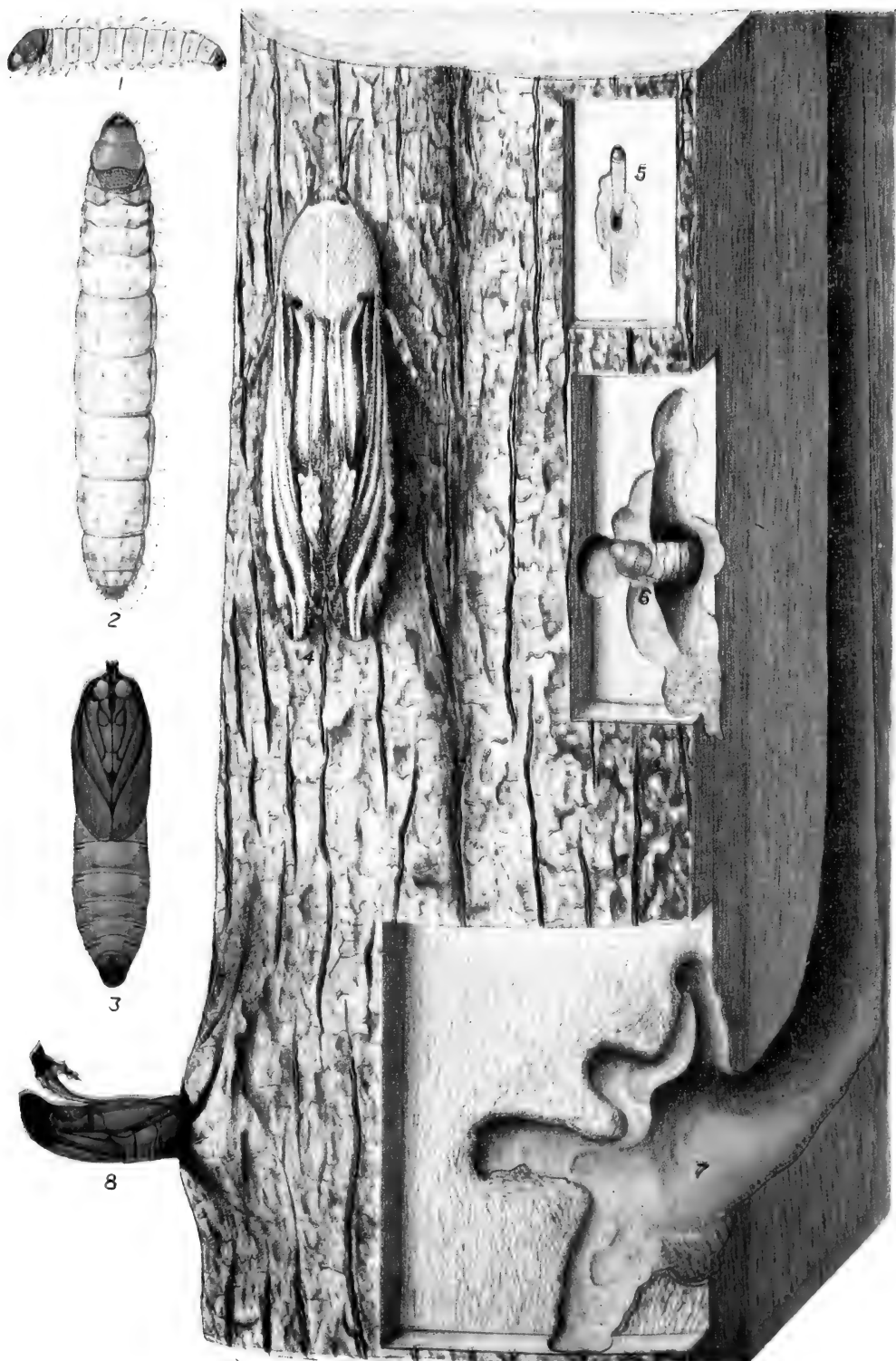
„ 5. Early stage larva in bast and bark chamber, with the commencement of an extension into the sapwood.

„ 6. Older larva with the sapwood chamber in early stages of development and the larval gallery already formed in the heartwood.

„ 7. Completed beehole after the emergence of the borer showing the extent of abandoned sapwood chamber in which callus growth is beginning to intrude.

„ 8. Pupal skin left in the exit-hole after the escape of the moth.

[NOTE.—All the above figures are approximately natural size.]



THE SEASONAL HISTORY OF *DUOMITUS CERAMICUS*, WILK.

del., J. B. Singh pinx.

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1— $1\frac{1}{2}$ inches long and $\frac{1}{8}$ to $\frac{1}{4}$ of an inch wide. A minute ejection hole and connecting gallery is maintained, through which particles of bark and wood dust and excreta are ejected. A careful scrutiny of the bark at this period will reveal a slight accumulation of dust in a fissure in the bark; the dust derived from the bark and first ejected is dark in color, while that ejected later, when the sapwood is reached, is white. If sap is abundant the particles of dust become gummed into small nodules and may hang in a bunch or loop from the ejection hole.

Mr. Unwin, whose observations made in June, 1916, agree with the above, records a case of one larva that apparently abandoned its original burrow and constructed a new one. He notes that "although the larva itself was fully $\frac{1}{2}$ an inch long, the hole was not more than $\frac{1}{4}$ of an inch deep in the bark."

CONSTRUCTION OF THE SAPWOOD CHAMBER AND BEEHOLE.

[Plate iii, Figs. 6, 7].

As the larva grows, the size of the bark and sapwood chamber is increased, both laterally and longitudinally and during the 3rd instar (if not earlier) it commences to bore a tunnel towards the heartwood. Numerous examples have been found of shallow sapwood chambers from which a gallery 1—2 inches long and $\frac{1}{4}$ of an inch in diameter extends inwards and upwards; such galleries represent early deaths due to parasitism, and contain usually the cocoons of hymenopterous parasites with the skin of the dead *ceramicus* larva. In the next instars the heartwood gallery is gradually excavated almost to the full length of the final beehole, and is only slightly extended and widened during the later stages of the larval life. The gallery always runs upwards and is more or less straight, but may show a spiral or sigmoid tendency. Its diameter is increased with the growth of the larva, but is always wide enough for the larva to turn round. It is apparently used as a retiring or moulting gallery.

The chamber in the bark and sapwood varies very much in shape and area; its usual form is a stellate or lobed excavation the arms of which extend into the living bark and outermost layers of sapwood; in its centre its depth is greater and increases in a funnel-shaped impression towards the mouth of the heartwood tunnel. In slow-grown trees the superficial extent of the sapwood chamber of larvae of equal ages is usually greater than in quick-growing trees; a typically developed chamber is about 3 inches square but shallow straggling burrows may occur 5 inches long. Over one or more of the arms of the larval chamber circular ejection holes are constructed, which when not in use,

are closed each with a papery operculum formed of particles of wood and bark in a matrix of sheet silk. A few fragments of detritus and a slight bulge in the bark above the chamber alone betray the presence of the borer.

THE FOOD OF THE LARVA.

The food of the larva is partly sap flowing from the intersected sapwood vessels and partly callus tissue. The growth of secondary tissue is particularly vigorous in the inner bark of the injured zone, and is formed of highly nutritious cells, that are browsed down by the larva. Short arms or branches of the chamber and early ejection holes, that have been abandoned by the larva, are filled with fresh callus in a relatively short time in vigorous trees, so that a constant food-supply is ensured. In less vigorous trees the larva finds it necessary to stimulate fresh merismatic activity by boring new extensions or recesses from time to time. The wood-dust derived from the excavation of the heartwood gallery, or beehole, is apparently not eaten by the larva, but is ejected at intervals through holes in the wall of the bark chamber.

MATURE LARVAL ACTIVITIES.

The larva continues to feed during the growing period of the host-tree, and, towards the end of the cold weather or as soon as the leaves fall, it prepares for pupation. The final constructional work of the mature larva consists in an upward elongation of the heartwood gallery to form a pupal chamber 2 to 3 inches long; at the same time the earlier work is corrected by smoothing down irregularities and removing debris, mainly in order to secure a continuous free passage from the pupal chamber to the exterior. The latest work, representing the construction and enlargement of the terminal portion of the beehole, and the correction of the curve at the junction of the vertical and horizontal portions of the beehole, is distinguishable by the lighter color of the wood contrasting with the dirtier surface of the earlier excavation. Before retiring to pupate the larva clears out a path through the sapwood chamber to the outer bark, and prepares an exit hole, which is roofed in with thin flakes of bark connected by means of silk. The ejection holes are also closed with flat discs or opercula of silk and fragments of wood, and usually an additional operculum is constructed across the mouth of the beehole, where it debouches into the sapwood chamber. The mature larva finally shuts itself in the pupal chamber with a loose wad of pale or

reddish-brown strands of silk, woven across the gallery for a thickness of about $\frac{1}{4}$ of an inch.

The construction of the beehole, as detailed above, does not agree with Stebbing's interpretation of the process; he states [1905, pp. 11 and 17.] "It is probable that it [the larva] only spends the monsoon months (with perhaps a portion of the preceding hot weather) in feeding and attaining its full size and towards the commencement of the cold weather tunnels into the tree." And six lines lower down, "it appears that the cold weather is passed through in the larval stage in Upper Burma perhaps partly in boring the pupating tunnel and chamber and that the larva only changes to the pupal or chrysalid condition on the approach of the hot weather."

In discussing the proposed steps to be taken to clear plantations of the borer, he states [p. 17], "It has been shown that the caterpillar feeds under the bark until full grown, and that on attaining full size it has to bore a hole through the bark to the outside so as to be able to eject through it the sawdust resulting from its tunnelling operations in the wood. A careful inspection of the trees at this period would enable the position of boring larvae to be ascertained and they could be removed *before* they had bored down into the wood." And again, [1914, p. 28] the larva of *Duomilus ceramicus* "tunnels down into the hard dry wood to pupate, but only when full-fed, and for pupating purposes alone."

The recent field-work does not support these views but tends to show that the heartwood gallery, *i.e.*, the beehole, is constructed gradually with the developement of the larva, and is used as a shelter for resting, moulting and finally pupating. Beekman's views [1919, pp. 10, 11] are in accordance with those of the writer.

PUPATION.

The pupal chamber is formed by the closure of the terminal portion of the beehole with a partition of silk; it is usually slightly less in diameter than the main portion of the gallery,* and is cleared of all fragments of dust and excreta.

The pupa lies in its chamber with the head directed downwards towards the exit, and the cast larval skin behind. Owing to the large number of free segments in the abdomen, it is capable of active movement if disturbed. Plate IV shows two beeholes in saplings, with the pupa *in situ* in the pupal chamber, the mouth of which is closed

* Stebbing [1905, p. 9] says that the pupal chamber "is slightly enlarged at its upper end, the enlarged portion being $1\frac{1}{2}$ to 2" in length," but the writer has found no instances of this type.

with woven silk. The pre-pupal portion of the gallery contains fragments of wood bitten out of the pupal chamber shortly before closure.

PUPAL HABITS.

EMERGENCE OF THE PUPA.

When mature the pupa leaves the pupal chamber and makes its way down the beehole. The silk wad plugging the neck of the pupal chamber is penetrated by the frontal spine as the pupa presses downwards; as the pupa continues to revolve and push, the silk mesh is separated and the strands flattened against the walls of the beehole. The pupa then continues its progress down the gallery by means of the leverage obtained from the rows of backwardly directed teeth on the abdominal segments. The alternate bending of the segments across the longitudinal axis of the body causes the alternate slipping and gripping of the teeth on opposite sides; the pupa is thus forced forwards but is unable to return backwards. On reaching the mouth of the beehole the frontal spine ruptures the operculum closing it, and the insect enters the sapwood chamber. Here it may encounter a certain amount of obstruction, such as mud brought in by termites or fossorial wasps, cells of leaf-cutting and solitary bees, ant colonies, or even callus growth, if the chamber was insufficiently cleared by the larva, or if emergence is delayed until the new growth of the tree has commenced. Having passed these obstructions the pupa pushes through the thin bark covering the exit hole, and rests for a longer or shorter period with its head at the level of the outer bark. On one occasion the pupa was observed to leave the pupal cell nearly 2 hours before the moth emerged.

EMERGENCE OF THE MOTH.

The actual escape of the moth occupies a few minutes only. The pupa works its way out of the bark, swinging its body in a spiral motion; at the same time the abdomen lengthens by extension of the intersegmental skin until the head of the pupa is able to come into contact with the bark of the tree. The whole of the thorax and 3 or 4 abdominal segments now protrude from the hole, further exodus being apparently controlled by the asperities on the cremaster. A split occurs dorsally along the middle line of the thorax, the chitinous cover of the head and antennae separates off in one anchor-shaped piece, and in a few seconds the moth walks directly out of the pupal case on to the bark of the tree.

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PHILIP H. KATZ

Professor of Economics, University of Chicago, Chicago, Illinois 60637
and
Professor of Economics, University of California, Berkeley, California 94720

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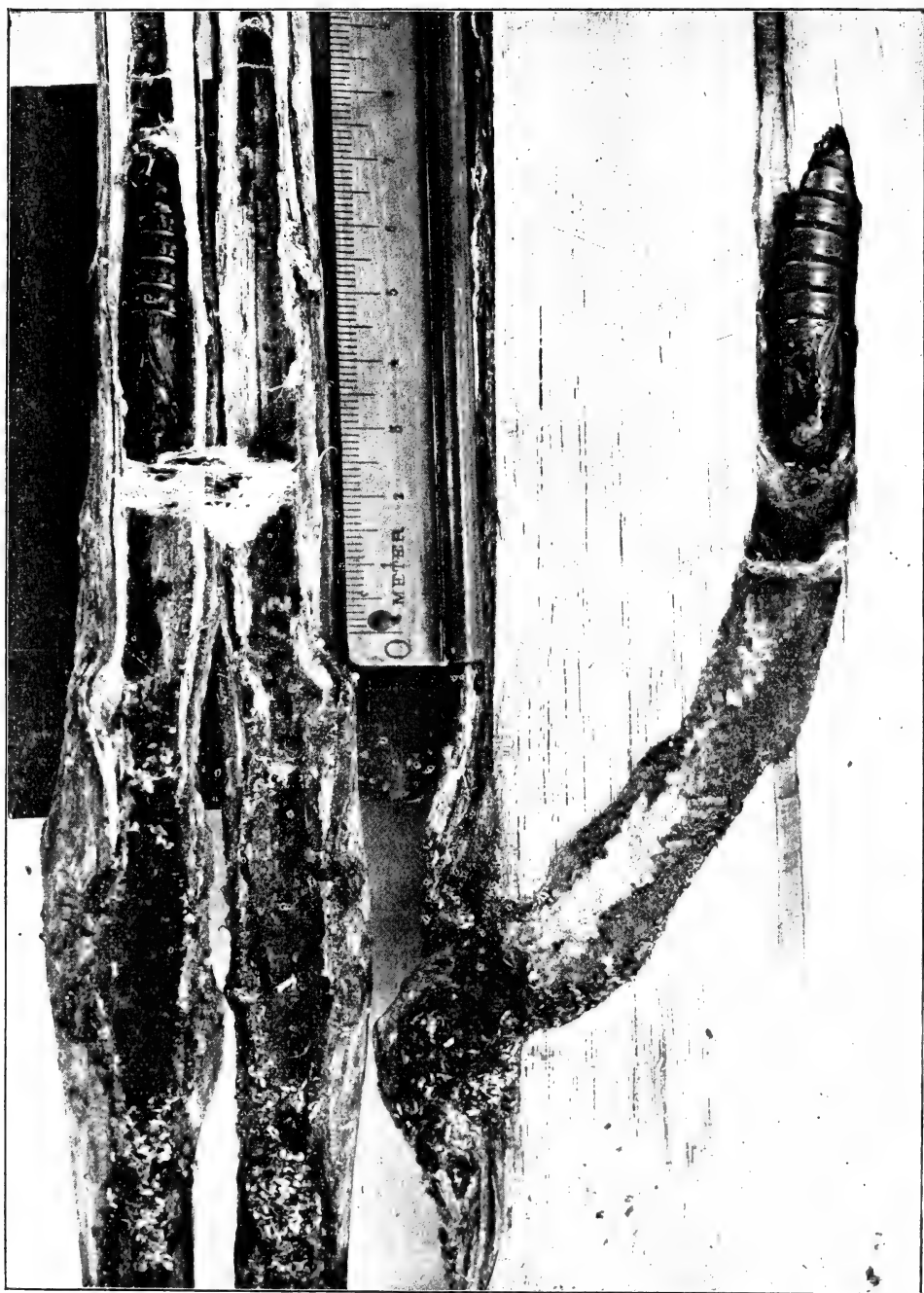
Description of Plate IV

PUPATION OF DUOMITUS CERAMICUS, WLK.

Longitudinal sections through beeholes in a very young teak sapling (left) and an older teak pole (right) showing the pupa *in situ* in the pupal chamber, which is closed by a woven silk partition.

(Slightly less than natural size).

[From Beekman, *De groote djati boorder*, Meded. v. h. proefst. voor het boschwezen, Java, No. 4, 1919, Plaat 5 ; by kind permission.]



DUOMITUS CERAMICUS, WLK.

[From Beekman, *De groote djati boorder*, 1919, Pl. 5; by kind permission.]

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The pupal skin remains protruding from the hole in the bark, until destroyed by birds, lizards, ants, etc.

The period during which the pupal skin may escape destruction has not been definitely ascertained, but from evidence of discoloration and general weathering it is considered that one to two weeks is not uncommon. On two occasions pupal skins charred by a fire that occurred some ten days previously have been noticed.

IMAGINAL HABITS.

DEVELOPMENT OF THE WINGS.

The moth on emerging from the pupal skin walks a short distance up the trunk of the tree until a position is found which affords good foothold, and protection from wind. At the end of some 25 minutes the wings are fully developed, but the moth as a rule remains motionless in the same spot until evening, or climbs up the trunk into the shelter of the crown without attempting to fly. The writer was fortunately able to observe the emergence of beehole borers under natural conditions in teak jungle; the following records are of typical instances.

Wing Development.

1. Hsipaw, Northern Shan States: 2nd May 1914: zero hour, 7-8 p.m.

- 0 minutes.—The moth, a female, emerged, and walked up the bole to the right of the exit hole for about 3 feet; abdominal segments fully extended; wings no longer than the pupal wing-sheaths.
- 5 ,, Abdominal segments considerably contracted; anterior pair of wings $\frac{2}{3}$ rds expanded, with the distal $\frac{1}{3}$ th curled.
- 8 ,, Abdominal segments contracted so that no white intersegmental skin is visible; wings extending almost to the end of the abdomen, spirally curled at tips.
- 9 ,, Wings opened and held vertically like a butterfly's wings; thorax and head raised and abdomen curved concavely so as to give free space to the wings.
- 11 ,, Scarcely perceptible undulations pass down the wings, accompanied by increase in length and uncoiling of the spirally twisted tips.

- 14 minutes.—Forewings developing rapidly, extend $\frac{1}{2}$ inch beyond the abdomen.
- 16 „ Forewings more fully developed, flat except for shallow depressions; hind wings still spirally folded at tips.
- 20 „ Rightwing nearly developed; left hindwing retarded.
- 25 „ Main development in length practically finished; forewings extending $\frac{3}{4}$ of an inch beyond the abdomen.
- 33 „ After maintaining the pose for 24 minutes, the moth suddenly closed the wings, dropped the thorax and straightened the abdomen.
- 35 „ Fore wings held slightly apart, showing slight irregularities on the surface; hindwings, especially the left, were not free from curves when the wings closed.
- 45 „ No perceptible change.
- 52 „ Moth moved the legs slightly and altered its position with reference to the air currents affecting it.
- 60 „ No perceptible change.
- 70 „ No perceptible change, except that the wings fit more closely together in the normal angle of repose.
- 71-120 „ Moth remaining motionless in the same position. Two hours after emergence the moth was removed to a cage, in which it remained motionless for several hours.

2. *Namma Reserve, Northern Shan States; 8th May, 1914, zero hour 1-5 p.m.*

- 0 minutes.—The moth, a male, emerged and climbed upwards.
- 9 „ Wings rapidly expanding; forewings spread out so as to expose hindwings.
- 10 „ Wings broadly curved with tips wrinkled; abdomen slightly curved.
- 10-5 „ Wings opened and held vertically; thorax raised and abdomen concavely curved; wings extend beyond the abdomen but are curved at tips.

12 minutes.—Wings flat and even.

14 „ Wings extending beyond abdomen by about $\frac{1}{2}$ an inch, separate at the tips, apparently fully developed. Antennae are held appressed to the sides of the thorax.

17 „ Moth moved a short distance to get into a breeze.

25 „ Wings opening and gradually diverging; body slowly straightening.

27 „ Wings very widely divergent; head dropped to level of femora.

28 „ Wings slowly lowered (after 13 minutes) but held in arrow-head pose and not suddenly closed as in ♀.

29 „ Wings tightly closed, accompanied by a few muscular tremors.

30-40 „ No perceptible change; removed.

There is considerable variation in the length of time occupied by the period of uphold; those individuals observed to emerge at higher temperatures developed more quickly than those at lower temperatures (or in rain) *e.g.*

Individual Number.	Sex.	Number of minutes to up-lift of wings.	Period of up-hold of wings.	Weather conditions.
1	♀	9	24	Warm, evening.
2	♂	10	32½	Rain, cold afternoon.
3	♂	10	19	Hot sun, afternoon.

The moth usually purges twice, once in the pupal skin on leaving and once some hours later.

TIME OF EMERGENCE.

The moth normally emerges during the day, usually near midday, in sunshine and in rain. The writer has found several newly-emerged individuals resting on the bark near the exit hole, with the wings scarcely developed and the pupal skin soft, and freshly wet with the meconium; such individuals are usually found during late afternoon and evening. As Stebbing says [1905, p. 12] "The moth probably issues at night and flies and pairs at night" it is desirable to record actually observed emergences.

Moth Emergence.

Date and Locality.	Hour or Conditions.	Observer.
15th April, 1914, Natural Forest, Katha.	One ♀, wings fully developed, near fresh pupal skin at 5 P.M.	C. F. C. Beeson
16th April, 1914, Katha .	One ♂ emerged in breeding cage between 11 A.M. and 3 P.M.	„
22nd April, 1914 . . .	One ♀ emerged in breeding cage between 1 P.M. and 2 P.M.	„
2nd May, 1914, Natural Forest, Northern Shan States.	One ♀ emerged at 5 P.M.	„
8th May, 1914, Northern Shan States.	One ♂ emerged in breeding-cage at 1-15 P.M.	„
Ditto . . .	One ♂ emerged in breeding cage at 5-17 P.M.]	„
23rd April, 1916, Shwegu .	One ♀ emerged in breeding cage between 1 P.M. and 3 P.M.	A. R. Villar.
27th April, 1916, Shwegu .	One ♂ emerged in breeding cage just before 11 A.M.	„
17th April, 1914, Natural Forest, Northern Shan States.	One moth with undeveloped wings and fresh pupal skin at 9-30 A.M.	B. P. Kelly.
20th April, 1914, Natural Forest, Shwegu.	One ♀ moth with developed wings and fresh pupal skin at 10 A.M.	G. F. Matthews.

The time of emergence and the ensuing period of inactivity obviously expose the moth to destruction by birds, lizards, monkies, etc.

FLIGHT HABITS.

Villar [1916, p. 513] describes the attraction of two male moths to a caged female at Okkyi, Shwegu sub-division; one arrived at 8 o'clock on the night of the 26th April, 1916, and the second at 11 o'clock on the following night. Mr. W. C. Rooke records in his diary for 30th March, 1917, at Kyungin, S. Toungoo. "Moths again kept coming round the light; whether the light attracted the moths or the other moths in the cage attracted them by calling I do not know."

The writer has tried attracting *ceramicus* moths with lights of various intensity up to 200 c.p., using petrol lamps with white reflectors, but without success, (possibly because the work was done in May and June at the end of the moth season). Mr. R. Unwin tried light traps in the first fortnight of June, 1916 without success. Mr. A. R. Villar tried to catch moths in April, 1916, by means of fires and lamps, but no specimens were seen. In view of these failures the following records are of interest. Dudgeon [1899, p. 645] says "I took 2 males of this species [*ceramicus*] at Punkabaree, Sikkim in July and August. It must be rare as I have never seen others." Seitz [1912, p. 418] says of the genus *Duomitus* "The moths fly late at night and strongly attracted by light," and of *D. leuconotus*, that "the natives collect the insects on tree-trunks as well as at the light, the insect coming to the street lamps in the towns." Of *Duomitus punctifer* it is said, that "the male is an active flyer and is frequently attracted to light. The female does not fly so readily, at least until after the eggs are laid." [Agric. News, Barbadoes, 1914, p. 328.]

STAGE DATES.

Field-data on the Seasonal History.

1. THE EGG STAGE.

No field records are available for the duration of the egg stage and the incubation period, but since captive moths lay eggs 2 or 3 days after emergence and have a short life the egg-stage may be considered as coincident with the moth stage.

2. THE LARVAL STAGE.

The subjoined table, Table 1, shows the dates on which larvae have been found in the field with their head measurements as body measurements are no reliable index to the age. It will be seen that the youngest larvae have been found as early as the 21st May, [Pyonchaung W. C. Rooke]; these, as all other young larvae collected, were in the 2nd instar. In the first week of June larvae of this size and slightly larger (1—0 to 2·0 mm. head width) have been taken by the writer in Pyinmana and Katha divisions. Larvae of similar or slightly larger dimensions have been taken as late as August [Petsut, J. W. Bradley]; Mr. Unwin notes of the Pyinmana observation area that "the new boring of newly hatched caterpillars takes place in the first fortnight of June" and records the discovery of larvae $\frac{1}{6}$ to $\frac{1}{3}$ of an inch long in bark

chambers formed between the 3rd and 15th June. He found new borings on the 17th and 25th June and on the latter date noted that larvae $\frac{1}{3}$ rd to $\frac{1}{2}$ an inch were prevalent to the exclusion of smaller sizes. New borings appeared between the 28th June and the 14th July. The available information suggests a very late appearance of larvae as compared with the moth emergence dates; either the incubation period of the egg is prolonged or the larvae hatching in the hot weather do not survive. From the feeding habits of the insect the writer is inclined to consider that the larval period begins slightly before the first rainfall, when the movement of sap commences in the tree, and that larvae hatching before the bast has resumed activity are either checked in their development or perish. There is evidently necessity for detailed investigation into the egg and first larval instar since these are apparently the most vulnerable stages, and about which least is known.

TABLE 1.—*Stage dates of larvae of Duomitus ceramicus, Burma.*

Date.	No. of Individuals.	Head measurements.	Locality.	Observer.
11th April 1907 . . .	1	3.45 mm. . .	Toungoo	Forest Zoologist.
18th April 1914 . . .	2	3.85—4.30 mm. . .	Petsut, Katha, S. T. 24.	Ditto.
21st April 1914 . . .	1	3.80 mm. . .	Okkyi, Shwegu; R. D. 43 ex beehole.	G. F. Mathews.
24th April 1914 . . .	1	3.70 mm. . .	Petsut, Katha, ex S. T. 28.	Forest Zoologist.
20th April 1919 . . .	3	2.95—3.25 mm. . .	Yanaungmyin, Pyinmana.	Ditto.
2nd May 1919 . . .	2	3.12—3.83 mm. . .	Kaing, Pyinmana, in heartwood gallery.	Ditto.
25th May 1919 . . .	1	3.75 mm. . .	Pyonchaung, North Toungoo.	Ditto.
21st May 1919 . . .	5	3.20—4.60 mm. . .	Mohnyin, Katha, ex beeholes.	Ditto.
31st May 1919 . . .	2	3.45—4.40 mm. . .	Okkyi, Shwegu . . .	Ditto.
21st, 30th May 1916	Several .	1.07—1.8 mm., some newly moulted.	Pyonchaung, North Toungoo; R. R. D. 150.	W. C. Rooke.
7th June 1919 . . .	Do. .	1.1 mm. . .	Petsut, Katha . . .	Forest Zoologist.
10th, 11th June 1918 .	Do. .	1.5—1.8 mm. . .	Yanaungmyin, Pyinmana.	Ditto.
5th June 1918 . . .	1	3.30 mm. . .	Ditto . . .	Ditto.
6th June 1919 . . .	3	3.10—3.80 mm. . .	Okkyi, Shwegu . . .	Ditto.
8th June 1919 . . .	2	3.90—4.15 mm. . .	Petsut, Katha, ex beeholes.	Ditto.
14th, 17th July 1918 .	6	2.05—2.87 mm. . .	Bondaung, South Toungoo; R. R. D. 468.	A. Lawrence.
August 1912 . . .	Several .	1.60—2.80 mm. . .	Petsut, Katha . . .	J. W. Bradley.
9th August 1917 . . .	2	2.75—3.10 mm. . .	Kaing, Pyinmana; R. R. D. 334.	A. J. Butterwick.
7th, 8th September 1914.	3	2.30—2.65 mm. . .	Kyaukkvi, Shwegu; R. R. D. 66, about 1½" deep in sapwood.	G. F. Mathews.
7th October 1918 . . .	4	4.0—4.25 and 4.80 mm.	Bondaung, South Toungoo; R. R. D. 488.	A. Lawrence.
19th November 1918 .	1	5.37 mm. . .	Pyonchaung, North Toungoo ex beehole.	W. C. Rooke.

The observations recorded above demonstrate the commencement of a generation early in the rains, but there are numerous examples of larvae of large size occurring at the same time as early instar larvae, which represent either very rapid or very delayed development. Much more work has to be done on the life-cycle, but as far as present observations go, one must conclude that some larvae take two seasons for their development.

3. THE PUPAL STAGE.

The following table shows the dates and localities on which pupae and fresh pupal skins have been observed.

TABLE 2.—*Stage dates of pupae of Duomitus ceramicus, Burma.*

Date.	Number of individuals.	Pupae or Pupal skins.	Locality.	Observer.
20th March 1914 .	3	Pupal skins .	Pyonchaung Reserve North Toungoo Division.	Forest Zoologist.
25th March 1917 .	2	Pupae . .	Kyungin, South Toungoo division.	W. C. Rooke.
4th, 6th April 1914	3	Do. . .	Mohnyin Reserve, Katha Division.	Forest Zoologist.
7th, 8th April 1914	3	Do. . .	Mandalay division.	B. P. Kelly.
13th April 1914 .	..	Do. . .	Namkha, North Shan States.	Forest Zoologist.
14th April 1914 .	5	Do. . .	Okkyi Shwegu Sub-division.	A. R. Villar.
18th, 19th April 1914.	2	Do. . .	Petsut Reserve, Katha division.	Forest Zoologist.
20th April 1914 .	1	Pupa . .	Okkyi Reserve, Shwegu Sub- division.	G. F. Mathew.
1st, 30th April 1914.	21	Pupal skins .	Petsut Reserve, Katha division.	Forest Zoologist.
1st, 30th April 1914.	..	Many pupae .	Bilumyo Reserve, Katha division.	Ditto.
1st, 30th April 1914.	..	Several pupae .	Mohnyin Reserve, Katha division.	Ditto.
April 1914 . .	1	Pupa . .	Northern Shan States.	J. H. Benson.
10th May 1914 .	1	Do. . .	Hsipaw, Northern Shan States.	Forest Zoologist.
1st, 24th May 1914	..	Many pupae .	Hsipaw, Seen, Northern Shan States.	Ditto.
May 1914 . .	10	Pupal Skins .	Hsipaw, Northern Shan States.	Ditto.
April-May 1914 .	34	Do. . .	Ditto . .	Ditto.
11th May 1916 .	..	Do. . .	Yanaungmyin, Pyinmana Division.	R. Unwin.
May 1918 . .	17	Do. . .	Pyonchaung Reserve, North Toungoo division.	Forest Zoologist.
14th, 25th May 1919.	11	Do. . .	Bilumyo reserve, Katha division.	Ditto.

4. THE MOTH STAGE.

The following table shows the dates and localities on which moths have been caught, bred out or recorded to have emerged.

TABLE 3.—*Stage dates of moths of Duomitus ceramicus, Burma.*

Date.	Number of individuals.	Locality.	Observer.
25th March 1914 .	Several	Pyonchaung Reserve, North Toungoo division.	Forest Zoologist.
27th, 30th March 1917	Do. .	Kyungin, South Toungoo Division.	W. C. Rooke.
15th April 1914 . .	1	Petsut Reserve, Katha division.	Forest Zoologist.
17th April 1914 . .	1	Mandalay Division . . .	B. P. Kelly.
Ditto . .	Several .	Hsipaw, Northern Shan States	Forest Zoologist.
20th, 21st April 1914 .	Do. .	Okkyi Reserve, Shwegu Sub-division.	G. Mathews.
22nd April 1914 .	1	Petsut Reserve, Katha division.	Forest Zoologist.
15th, 26th April 1914 .	Several .	Ditto ditto . . .	Ditto.
Ditto. .	Do.	Mohnyin Reserve, Katha Division.	Ditto.
1st, 25th May 1914 .	3	Hsipaw, Northern Shan States.	Ditto.
1st, 25th May 1914 .	Several .	Se En, Northern Shan States.	Ditto.
20th March to 1st June 1916.	211	Pyonchaung, Northern Toungoo division.	W. C. Rooke.

In Pyonchaung, N. Toungoo, Rooke noted that out of 211 moths 168 emerged before 6th May 1916 and 43 between 7th May and 1st June 1916; early larval work was not discovered in this area until 23rd May. In 1918 in the same locality the Forest Zoologist found 45 fresh pupal skins and 71 empty emergence holes between 21st and 30th May.

Unwin notes for Pyinmana that "the moth emerges at latest by the middle of June." On the 15th June, 1916, 8 fresh emergence holes were found which were not present on the 3rd June.

Villar in Okkyi, Shwegu records that moths emerged from 22nd April to 12th May.

Natural enemies.

WOODPECKERS.

Species.—Stebbing [1905, p. 12] considered that "the chief enemies of the "beehole" borer would seem to be woodpeckers" and observed that there are at least two species, that attack it, "the one blackish-green, and the other greyish-green." In his Manual of Forest Zoology [1908, p. 192] *Tiga javanensis* (which is neither blackish-green nor greyish-green) is referred to as "the species which feeds upon the caterpillars and pupae of the beehole borer of teak (*Duomitus ceramicus*)."

During April-June the writer shot numerous specimens of 8 of the larger species of woodpeckers, and examined their stomach-contents.

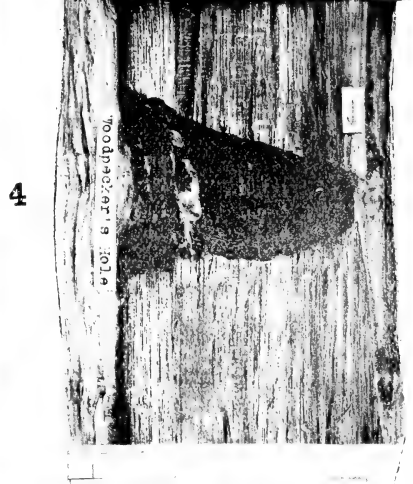
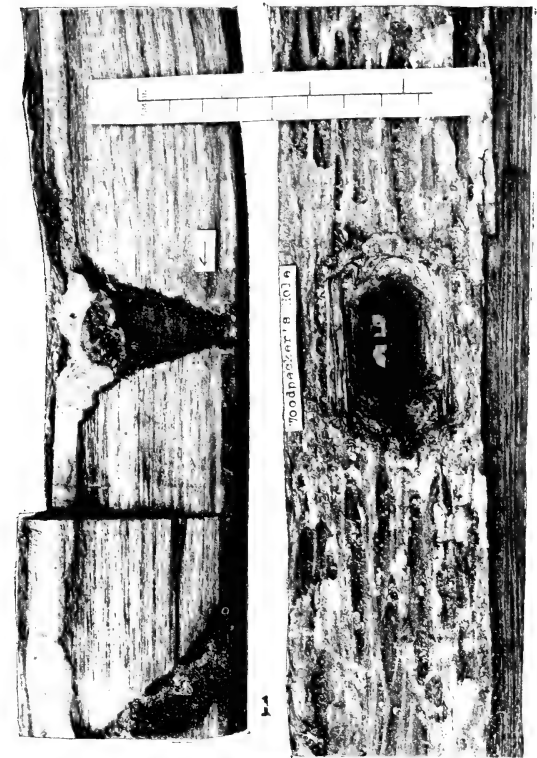
Description of Plate V.

WORK OF WOODPECKERS IN BEEHOLES.

FIGS. 1, 3, 4, 5. Longitudinal sections through holes made by woodpeckers into the galleries of *Duomitus ceramicus*, and subsequently overgrown.

FIG. 2. Surface appearance of woodpecker holes a few months after excavation, before formation of callus ingrowth.

FIG. 5. is probably the work of the great slaty woodpecker, *Hemilophus pulverulentus*; the remaining holes are those of *Chrysocolaptes* and allied genera.
(About one half natural size, *vide* scales in inches and centimeters).



WORK OF WOODPECKERS IN BEEHOLES.

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In two cases only were remains of *ceramicus* larvae recovered [6th May 1914, Hsipaw; June 1918, Bondaung]; both birds were Tickell's Goldenbacked woodpecker, *Chrysocolaptes gutticristatus*. All other stomachs examined contained insect remains, e.g., Formicidae, *Oecophylla smaragdina*, *Camponotus compressus*, *Monomorium* sp.; Apidae, *Apis indica*, *Melipona* sp., globules of bees-wax; Buprestidae, beetles and larvae; Longicornia, larvae and pupae; Termitidae; Lepidoptera, defoliating caterpillars; etc., and large quantities of fruits of *Ficus*. Of insects ants are by far the commonest food. There are, however, several sizes of hole made by woodpeckers into a beehole, the smallest and average of which might be made by a bird of the size of *Chrysocolaptes* or *Tiga*, but the largest sizes are of such dimensions that only the great Slaty Woodpecker, *Hemilophus pulverulentus*, can be responsible for them.

Importance as controlling agents.—The conspicuous appearance of the work of woodpeckers has naturally created for these birds a reputation as important natural checks on the numbers of the borer, but has also caused them to be considered as serious pests of teak timber.

As Stebbing states [1905, p. 14] "although these birds are present in the forest in the guise of friends, their attacks on the trees are to be feared almost as much as those of the insects," and [*l.c.*, p. 18] "in the interest of the timber it cannot be held that the bird counterbalances the evil it does by the number of insects it destroys." The following figures give a different aspect and possibly truer indication of the economic importance of woodpeckers with relation to the beehole borer.

TABLE 4.—*Incidence of Woodpecker Attack on Beeholes, Burma 1918-19.*

Locality.	Number of Beeholes.	Number of Woodpecker's Holes.	Percentage of Woodpecker Attack.
Bilumyo, Katha . . .	21	6	35.0
Petsut, Katha . . .	222	39	17.6
Konbilin, Tharrawaddy . .	25	4	16.0
Mohnyin, Katha—			
(a) plantation . . .	117	11	9.1
(b) natural forest . . .	246	20	8.1
Bondaung, South Toungoo . .	65	7	10.9
Kaing, Pyinmana . . .	56	6	10.7
Yanaungmyin, Pyinmana (a) .	175	8	4.5
Ditto Ditto (b) . .	412	9	2.1
Okkyi, Shwegu . . .	603	40	6.6
Pyonchaung, North Toungoo .	225	2	1.0
TOTAL .	2,167	152	7.0

The low mean percentage of 7.0 for all sample plots is unexpected ; (the figure of 35 per cent. for Bilumyo, Katha is hardly typical as it is based on a very small number of beeholes and is for a short period of years). Assuming that half the pupae destroyed in beeholes were females we have 3.5 per cent. as the reduction in the numbers of the borer due to woodpeckers during the last 40 or 50 years. If overgrown woodpecker holes are examined it will be found that the time of attack is almost invariably **after** the close of the season's growth, and that no callus is formed until next year's ring commences to grow, *i.e.*, it is the completed beehole containing the pupa or resting larva that is attacked and at a time when possibly food is scarce elsewhere.

The absence of signs of woodpecker attack on the early stages in the formation of the beehole is striking, and may be due to a more abundant alternate food-supply, but may also be due to the fact that the larva is probably within reach of the bird's long tongue, inserted through the entrance hole in the sapwood chamber, and is extracted without the necessity for further excavation in the wood. Analyses of woodpeckers' stomach-contents towards the close of the rainy season are required.

Woodpeckers' holes are healed up in vigorous trees in the course of one year's growth, but in less vigorous trees they require 2 or 3 years to close up completely, particularly if tenanted by ants, earwigs, etc., and in suppressed trees may remain open for long periods. In the last case local decay of the timber not infrequently occurs, but in well-grown trees the wood around a woodpecker hole remains quite sound as around a beehole. [*vide* Plate VI, lower figure]. Plate V shows overgrown woodpecker holes of various ages ; the largest, [Fig. 5], is probably the work of *Hemilophus pulverulentus* and the rest [Figs. 1—4] are probably formed by *Chrysocolaptes* and allied genera.

PARASITES.

Very little attention has been paid to parasites, as the field work was carried out mainly during the moth and early larval stages. The following observations indicate that investigation in this direction is desirable.

1. *Tachinidae* ? The beehole borer larva is parasitised by a tachinid fly, possibly by 2 species, as puparia of 2 sizes have been found. The empty pupal skins of the parasite have been found in several localities in half-formed and full-sized beeholes, sticking to the wall of the beehole in groups of 10 to 20. Live pupae of the fly were taken inside the dead body of a nearly mature borer caterpillar in

April at Mohnyin, but no flies were reared owing to hyperparasitism; from one pupa 74 hyperparasites were bred out.

Beekman [1919 p. 13] records parasitism by a tachinid in Java, and gives a description of the fly.

2. *Hymenoptera*.—At least one species of hymenopterous parasite attacks the borer and pupates in or alongside the larval skin of the host, after preparing a tough cocoon. This species has been found only in small larval galleries up to 2 inches in length.

3. The caterpillars of the borer are attacked by a fungus, ? *Cordyceps* sp., when half and full-grown, the hyphae of which replace the body tissues; when mature a long stalked fructification is sent out through the exit-hole.

In order to obtain an index of the mortality among young *ceramicus* larvae from parasitism or from other causes, the beeholes of the stem analyses were classed roughly into small larval galleries under 2 inches, and beeholes over 2 inches. The proportion of the former to the latter was found to vary from 0.2 to 3.3 times the number of the latter.

Other Beehole Borers of Teak.

In addition to *Duomitus ceramicus*, Wlk., teak is attacked while living by other borers, the galleries of which may be reasonably termed beeholes, and are undoubtedly so termed by the timber trade. The writer proposes to deal with these insects in a future Record, but the following notes are given so that their work may be distinguished from the true beehole borer.

PHASSUS SIGNIFER, Moore. [Hepialidae.]

The caterpillar of this moth bores a gallery in the heartwood which is carried from the mouth in the sapwood in a vertical direction *downwards*. *Duomitus ceramicus* on the other hand always carries its heartwood gallery *upwards*. The beehole of *Phassus signifer* is frequently of great length; specimens have been collected over 20 inches long. Its sapwood chamber is protected by a thick mat made of particles of bark and wood excrement woven together with silk. The mat is often larger than the palm of one's hand.

An allied species *Phassus malabaricus*, Wlk. attacks teak in Southern India.

ARISTOBIA BIRMANICUM, Gahan. [Lamiidae.]

The larva of this beetle forms a gallery in the heartwood of teak 2—3 inches long, oval or compressed in section and with two short arms to

the outside so that its appearance in longitudinal section is square bracket-shaped. ..[..Inside the gallery there is usually a mass of long fibres tightly packed against one end.

HAPLOHAMMUS CERVINUS, Hope. [Lamiidae.]

This species forms a similar gallery usually of smaller dimensions.

An unidentified species, presumably a lamiid, bores long galleries in the pith of epicormic branches, and yearling shoots, which are carried into the heartwood of the tree along the line of origin of the branch. These are frequently attacked by woodpeckers, and when overgrown simulate beeholes, but the replacement of the sapwood chamber by the circular emergence hole of the beetle serves as a means of identification.

The borers mentioned above are typically pests of saplings and small poles.

PART IV.

Statistical Methods.

The general principles on which the collection of statistical data on the incidence of the beehole borer is based, have been evolved gradually during the past two seasons' work. Without going into details of rejections and failures the following discussion of the method adopted, is presented and it is hoped that it will be of use in future investigations.

SAMPLE PLOTS.

In order to compare the relative degrees of attack in different areas of teak forest it is necessary to reduce observations to a common basis. The chief variables are (a) the age of the stand, (b) the number of sample trees taken, and (c) the distribution of the sample trees in the girth classes of the stand sampled. The most convenient means of comparison is found to be the mean sample tree, both for the total beehole incidence and for the annual incidence of attack. Firstly, the stand to be sampled should be enumerated in 3 inch girth-classes to determine its composition, and, secondly, the sample trees selected for analysis should be distributed proportionately throughout the girth-classes, so that the arithmetic mean sample tree of either series of measurements is approximately the same. The minimum number of trees for analysis, that will give a fairly close indication of the incidence, appears to be 10* for crops over about 20 years of age. In stands of less age, and in localities where the abundance of beeholes is low, a higher minimum number is required.

ANALYSIS.

The sample trees are girthed at 4' 6", and sawn up in lengths of 9 inches from soil-level upwards. This length is found to be the most convenient for splitting; in small poles double billets of 18" may be used. The billets are serially numbered from the base upwards, quartered and split into small wedges until every trace of the work

*In the Yanaungmyin Sample Plot, the incidences of trees in groups of 5 selected at random from the total number of sample trees (67) was compared, and it was found that as far as the annual incidence was concerned 5 trees gave sufficiently accurate results but with regard to the girth-beehole value the results were not uniform.

of the beehole borer is detected. In the records of this note all larval galleries of over $1\frac{1}{2}$ inches in length have been classed as "beeholes." Early larval work of smaller dimensions and scars on the sapwood have not been included in the beehole incidence, although they have been dated and recorded as subsidiary information on the annual frequency of attack. Where a beehole runs from one billet to the next above, it is recorded in the billet in which its base occurs.

THE DATING OF BEEHOLES.

[*Vide* Plate VI.]

As is pointed out in the section dealing with the life-history of the borer, it is believed that the life-cycle is normally annual. The age of a beehole can therefore be determined by counting the number of annual rings in the wood overlaying the sapwood chamber and the aperture of the beehole.

The most convenient method of obtaining cross-sections for the examination of the annual ring is to hold the wedge containing the mouth of the beehole at about 45 degrees on a chopping-block and to cut vertically with a heavy curved dah. The oblique surface so obtained expands the annual rings, and emphasises the presence of the larger pores and lines marking the spring wood. From time to time it is advisable to examine the cross-sections of the scars representing embayments and lobes of the sapwood chamber and callus in the mouth of the beehole, to locate the actual zone of attack. Error in dating frequently occurs unless several readings are taken.

The Annual Ring.—The annual ring of teak is marked by a zone of large and very conspicuous vessels, that is formed when the year's growth recommences. Outside this zone the vessels decrease in calibre, at first suddenly, and then gradually, attaining a minimum in the outer zone of the autumn wood. In some trees the later-formed small-pored wood contains sparsely scattered large vessels, but in almost all cases there is no difficulty in recognising a true ring. Very little information is available on the histology of the annual ring in teak, but for the accurate dating of beeholes it is essential to know the process of formation of the large pore-ring. Mr. Rodger is of opinion that the pore-ring in teak is formed in Burma between the beginning of May and the end of July or August, and that the autumn wood is formed between August and December. He considers that the rest period during which no wood is formed, lasts during January to about April.

IV. 1917 to 1919

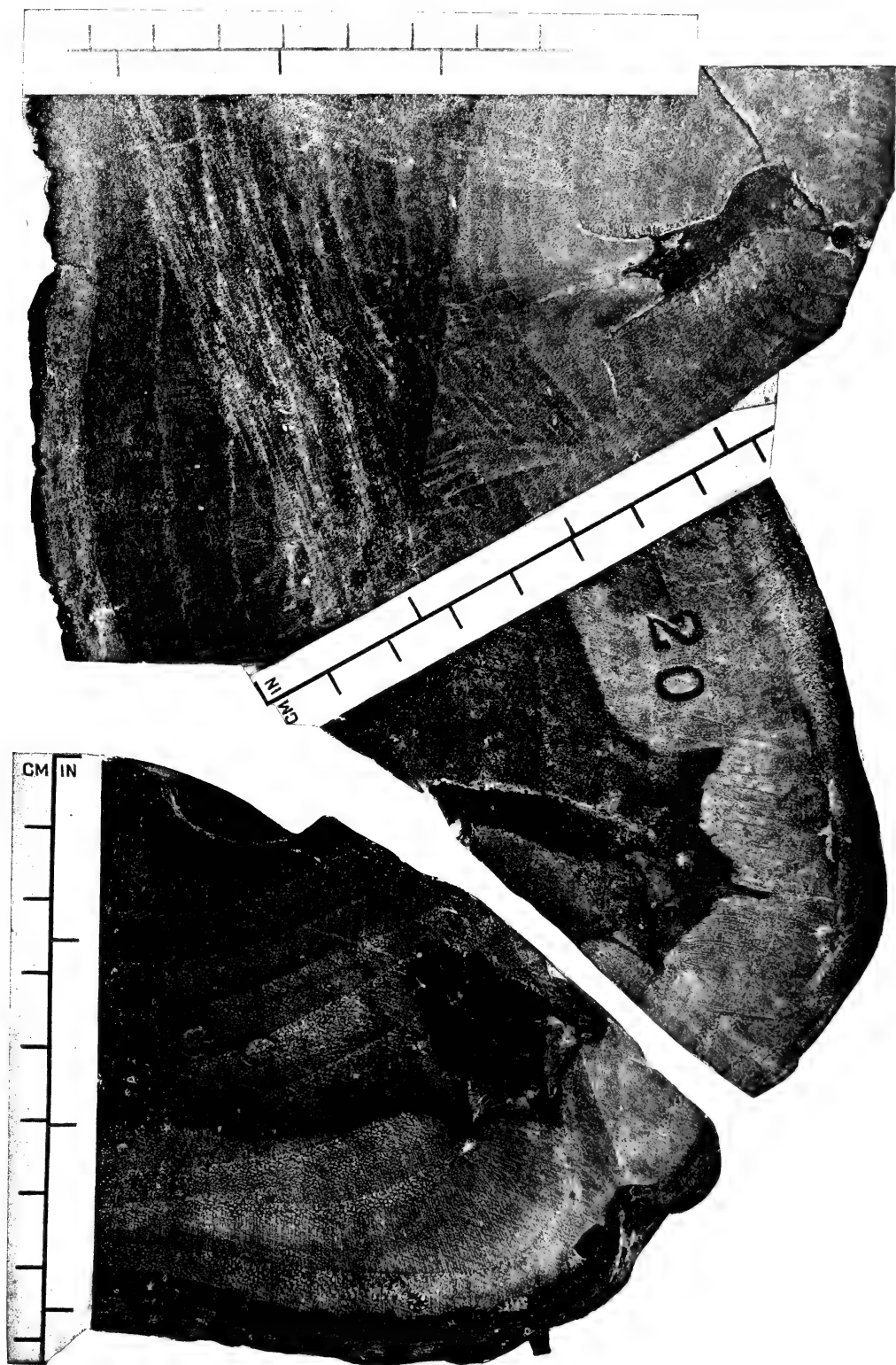
The first of the three years covered by this section is the year 1917. In 1917 the total number of cases was 1,000. In 1918 the total number of cases was 1,200. In 1919 the total number of cases was 1,100.

Description of Plate VI.

Transverse section through overgrown beehole showing formation of callus lobes in the mouth of the sap-wood chamber, and the appearance of the annual rings, antecedent and postcedent to the attack.

The upper and middle sections are of beeholes, the lower section of a woodpecker's hole.

(Natural size, *vide* scales in inches and centimeters).



TRANSVERSE SECTIONS THROUGH OVERGROWN BEEHOLES.

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The writer has not been long enough in one spot to estimate the time taken for the formation of the large pore-zone but there are indications that it is rapid, *i.e.*, 2 or 3 weeks. A number of trees examined in various stages of leaf formation appeared to show that the formation of pores is coincident with the appearance of the new leaves, but isolated vessels may be formed, when the buds are swelling and only a few have opened.

The large vessels are first formed singly or in lateral groups of 2 and 3, and when the bark is removed they separate easily from the cambium and appear on the tangential surface of the autumn wood as conspicuous ridges. Almost complete pore-zones, one vessel thick, occur when the leaves are still limp and not fully expanded, and a certain amount of intervacular tissue is formed before the flush of leaves is complete.

The short time occupied in the formation of the pore-ring gives a sharply defined period from which we can date the attack of the borer larva. From what is known of the life-cycle it is probable that the majority of larvae make the initial excavation in the wood at a time when the pore-ring is in active process of formation, and the outermost zones of sapwood are flooded with sap. There is, nevertheless, a large number of larvae, that make their attacks before or after the pore-ring is formed. The criteria by which the date of attack may be determined are the effect on the pore-ring and the age of the callus.

The effect of the three kinds of attack on the pore-ring may now be considered.

1. Before Pore-ring Formation. A larva attacking before growth is resumed bores a shallow groove in the autumn wood of the previous season. When the cambium renews activity the effect of the injury is marked for some distance on all sides of the wound. The vessels formed in the pore-ring on the surface of the autumn wood decrease in size and thin out as the ring approaches the excavation, and in their place dense homogenous tissue is formed, often inseparable from the wood of the previous year. As the annual ring continues to grow the larva enlarges its excavation and extends the chamber deeper into the sapwood, cutting through the pore-rings of previous years. The criteria by which this type of attack is dated are a normally formed pore-ring sharply excised by the margins of the sapwood chamber or beehole, followed by an abnormal or incomplete pore-ring in which the vessels disappear in the direction of the wound.

2. During Pore-ring Formation. An initial attack taking place while pore formation is in process affects the building of tissues near the wound in various ways. If the pore-ring is not far advanced its

severed ends show dwarfed vessels ; if nearing completion it may display a very localised effect, that is difficult to detect, or it may be stimulated to produce a diffuse mass of small pores extending into the outer wood. Often the later excavations of the larva remove the abnormal portions of the pore-ring, and produce a clean-cut effect on its boundaries, that simulates an emargination of a normal pore-ring. In doubtful cases the best criterion is the pore-ring of the first year's overgrowth.

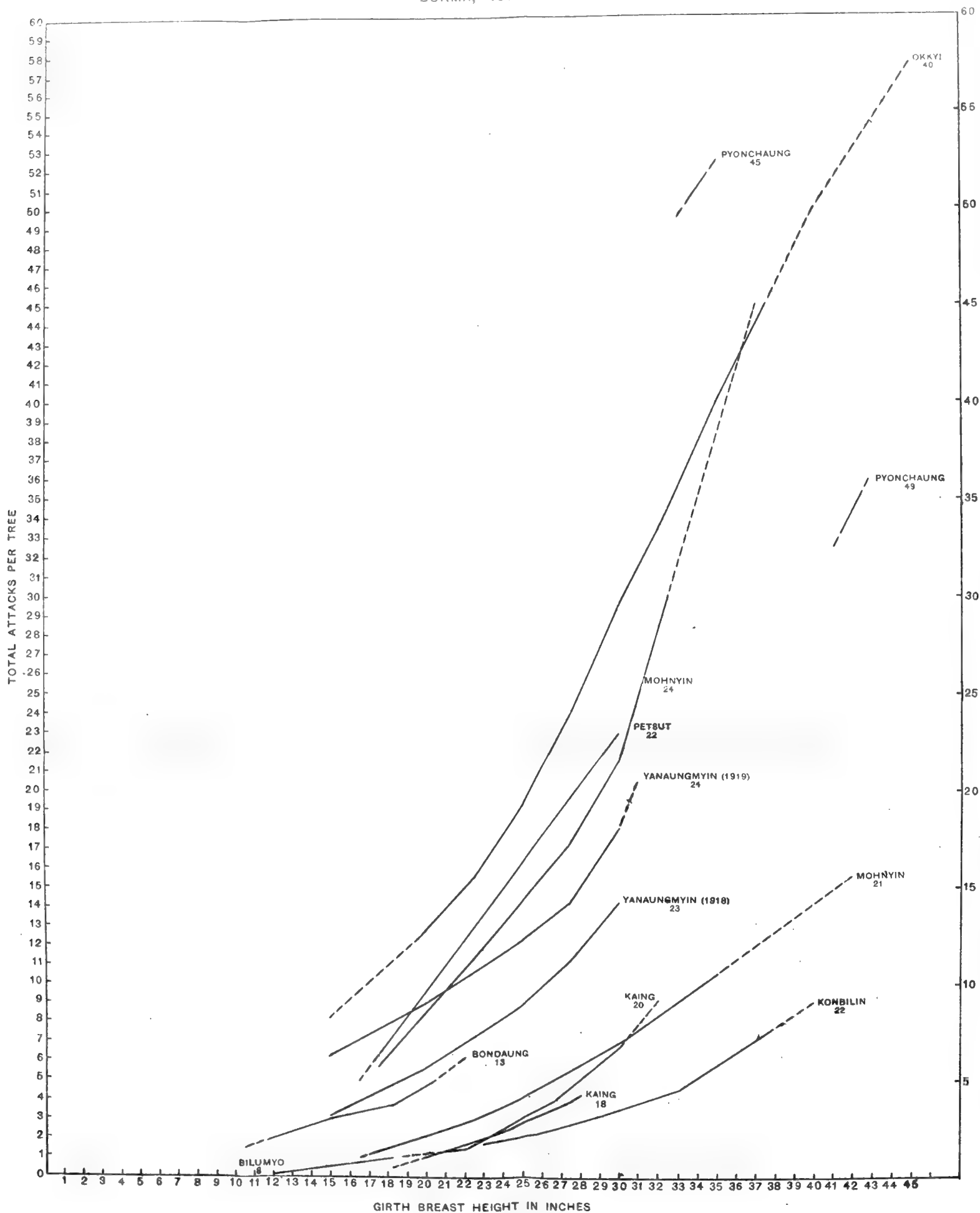
3. After Pore-ring Formation. A larva which does not bore into the wood until after the zone of pores and a certain amount of the small-celled wood is formed, cuts through the pore-ring of the current year in the same way as it cuts the rings of previous years and the effects are indistinguishable. But the initial injury to the cambium causes the production of a line or narrow zone of large pores resembling a false ring and extending for a short distance on either side of the wound. The presence of a short false ring is very common in fast grown trees, but it is often absent in suppressed or nonvigorous trees. In the false ring the medullary rays usually run straight through without deflection, but in a true ring several of the alternate rays are slightly diverted and form an angle at the junction of the "autumn" and "spring" wood.

Overgrowth or Callus-formation.—In fast grown trees no difficulty arises in the dating of a beehole ; the annual ring is broad and the callus formation is rapid and easily visible. The sapwood chamber is filled with callus and two lobes extend into the mouth of the beehole during the following year after the moth has emerged. It may be safely assumed that emergence in the majority of cases occurs during the hot weather, *i.e.*, before pore-ring formation starts, and the date of emergence can therefore be used to fix the date of attack in doubtful cases. In suppressed trees some years may elapse before lobes of callus enter the cavity ; in such cases the annual ring of the year of emergence is often recognisable by a departure from the parallel of concentric arrangement of the preceding normal rings. The attack of the insect usually stimulates increased growth in width at a short distance from the site of injury, which persists for several years. Examples of this type are more easily dated at a distance of an inch or two from the scar than at the beehole itself. [*Vide Plate VI*].

The year of attack is recorded as that following the first normal pore-ring or that preceding the year of callus formation, whichever is the more readily determinable. When it is not ascertained whether the larva attacked before or after pore-ring formation the error in the date of attack is within the limits of ± 1 .

GIRTH-BEEHOLE INCIDENCE CURVES
BURMA, 1918-1919.

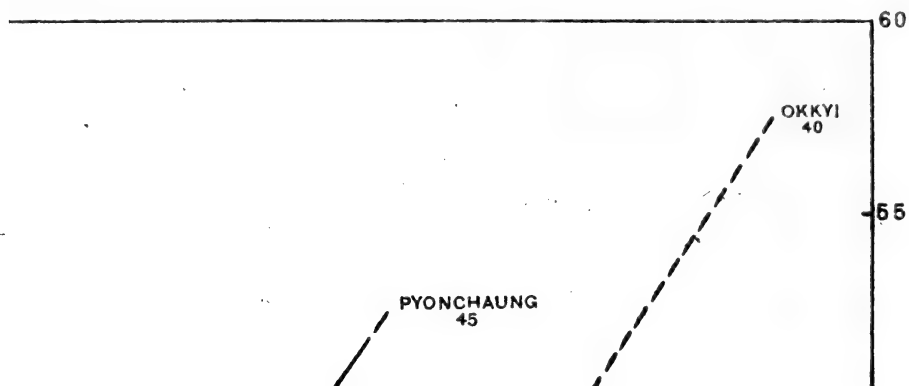
DIAGRAM 1.



ENCE CURVES

DIAGRAM 1.

-1919.



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THE GIRTH-BEEHOLE INCIDENCE.

[*Vide* Diagram 1.]

For each sample plot the arithmetic mean number of beeholes per girth-class and the arithmetic mean girth for that class is determined. Where adjacent girth-classes show very divergent means, as may occur with small numbers of sample trees, adjustment is made by grouping 2 or more girth-classes together. The beehole values are plotted as ordinates against the corresponding girth values as abscissae, and a curve drawn with reference to these points. This curve shows the probable number of beeholes occurring in an average tree of given girth in the area sampled.

The Girth-Beehole Incidence curves obtained in the sample plots recorded in this note are shown together on the same scale in Diagram I. It will be seen that in all there is a constant upward tendency, which in the older plots becomes very steep. Each curve was drawn as soon as the data were obtained in 1918 and 1919, without reference to the other curves. The marked parallelism, which appears when all curves are plotted together, is therefore intrinsic and not due to personal equation. By the graph method the curve of any one set of observations is directly comparable with that of another set, whether the trees analysed be of normal or abnormal growth, or the several plots of different ages, provided the individual plots are even-aged. In mixed stands of uneven age, interpretation, though possible, is more difficult. Any sample plot of which the curve lies vertically above that of another plot may be described as "more badly attacked," or, more correctly phrased, has, on an average, a greater total number of beeholes per tree girth for girth.

From the girth-beehole graphs it is evident that the number of beeholes per tree is directly proportional to its girth in a stand of even-aged trees, and that the number of beeholes also increases with age but at a different rate for each girth. In order to make absolute comparison of plots of different ages it is necessary to eliminate the girth factor, and express the intensity of attack by an index based on the beehole-age relationship.

THE AGE-BEEHOLE INCIDENCE.

The only available data on the relation between Age and Girth in teak plantations in Burma is contained in Diagram III of Forest Bulletin

No. 2*. Taking the data of this bulletin as a standard the following operations are carried out :—(1) the girth of the mean tree in a plantation of known age is ascertained from the curve in Diagram III, (2) the number of beeholes occurring in a tree of this girth is read off the girth-beehole incidence curve for the plantation, and (3) this value is then plotted against the age of the plantation. A curve drawn through these points will give the Age-Beehole Incidence.

In the following records the index of attack for a sample plot is usually expressed in the terms of Leete's normal tree, but in some cases the quality growth of the area sampled departs considerably from this mean. It has therefore been necessary in these cases to make an arbitrary selection of a mean sample tree on which to base the index of attack. The position of the arithmetic mean sample tree value with reference to the girth-beehole curve has been used as the principal check. If an extensive enumeration of the stand, in which the sample plot is situated, is carried out, it is preferable to use the mean sample tree arising from these measurements, in place of the data available in Forest Bulletin 2.

ANNUAL INCIDENCE.

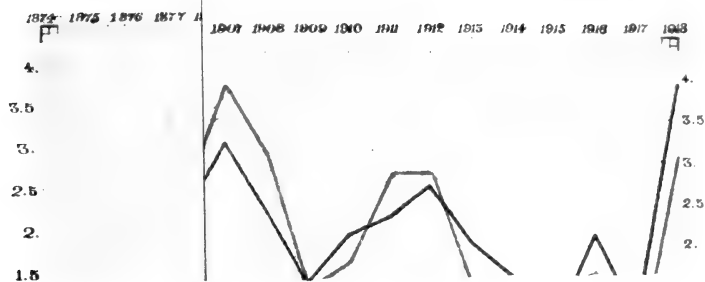
[*Vide* Diagram 2.]

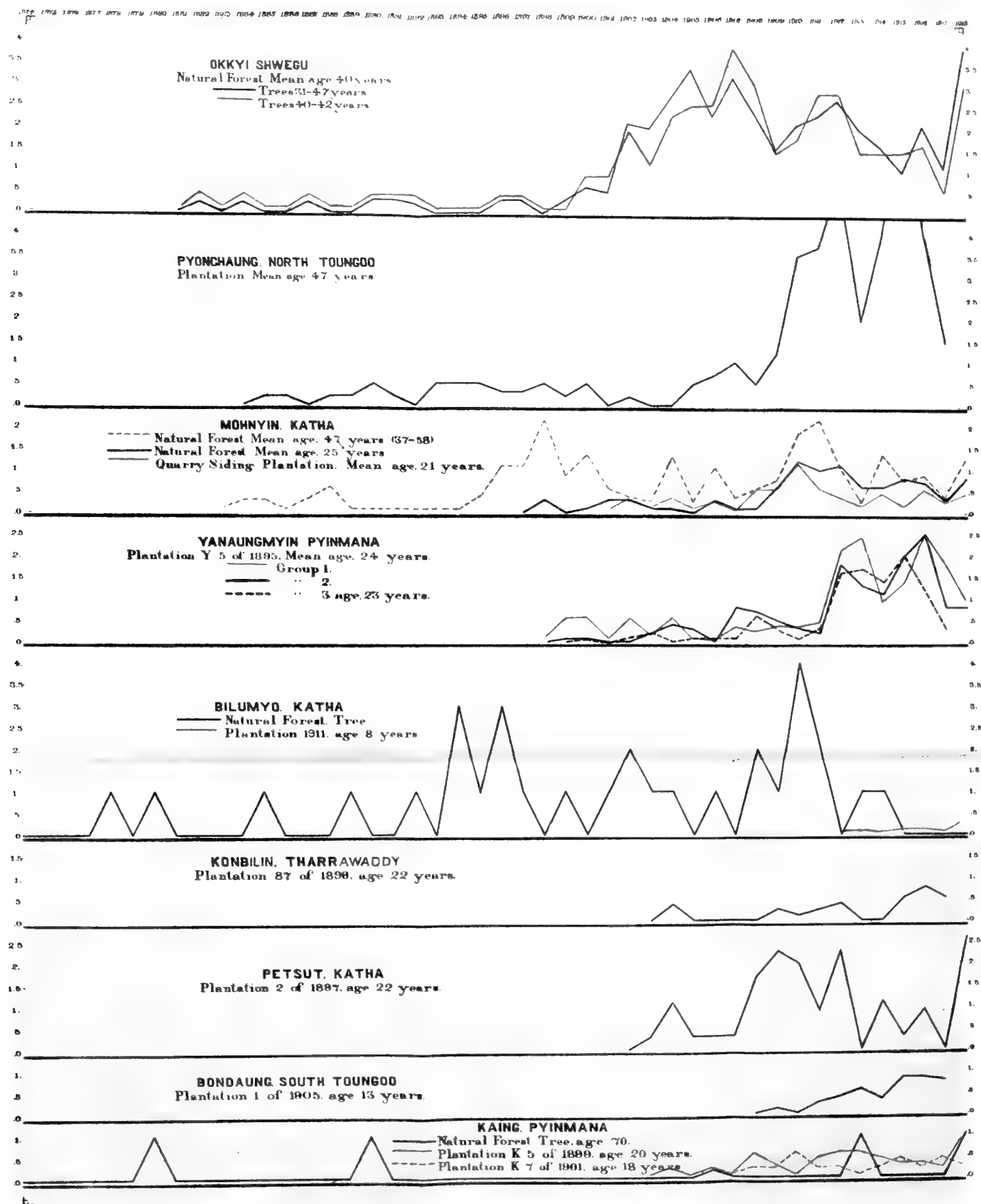
The annual incidence of the plot is obtained by adding together the data of all trees in which every beehole can be accurately dated. If one or more of the beeholes cannot be satisfactorily dated it is advisable to reject the whole tree from the annual incidence figures. The annual totals so obtained are then proportionately reduced to the quantities for the mean tree ; that is, the sum of the annual attacks on the mean tree is equal to the index of attack, *i.e.*, its girth-beehole value. These quantities are termed in the Tables of Annual Incidence that follow, the Reduced Values. In the Annual Incidence Graphs in Diagram 2 considerable fluctuation occurs in the current annual incidence, but the mean annual incidence on the whole steadily increases, though relatively slowly. It is probable that the apparent variation in the annual incidence is due more to the magnification of localised variations (owing to the small number of sample trees) than to other causes. The mean annual incidence is a truer indicator of local incidence.

*“Memorandum on Teak Plantations in Burma,” F. A. Leete, Forest Bulletin, No. 2, 1911.

BEESON-BEEHOL

DIAGRAM 2.





SAMPLE PLOT RECORDS.

1. Sample plots in Katha Division.

1. REGENERATION AREA, BLOCK I, COMPARTMENT I, BILUMYO RESERVE.

1. Description of the Sample Plot.

Growth.—Part of the natural regeneration area of 1911 (about 3 acres) was planted up, $6' \times 6'$, with natural seedlings removed from fully-stocked areas. The growth is excellent (mean girth of 40 trees=15 inches, *i.e.*, $2\frac{1}{2}$ inches above normal).

Undergrowth.—Absent or negligible over the greater part of the area ; trees 35 and 36 over fairly dense grass.

Past History.—The whole block was burned before regeneration in 1910-11, thereafter protected until 1918 when a small portion of the regeneration area was departmentally burned. In 1919 the remainder of the area including sample plot was burned. A light thinning was made in December—March, 1918-19.

2. Results of Analyses.

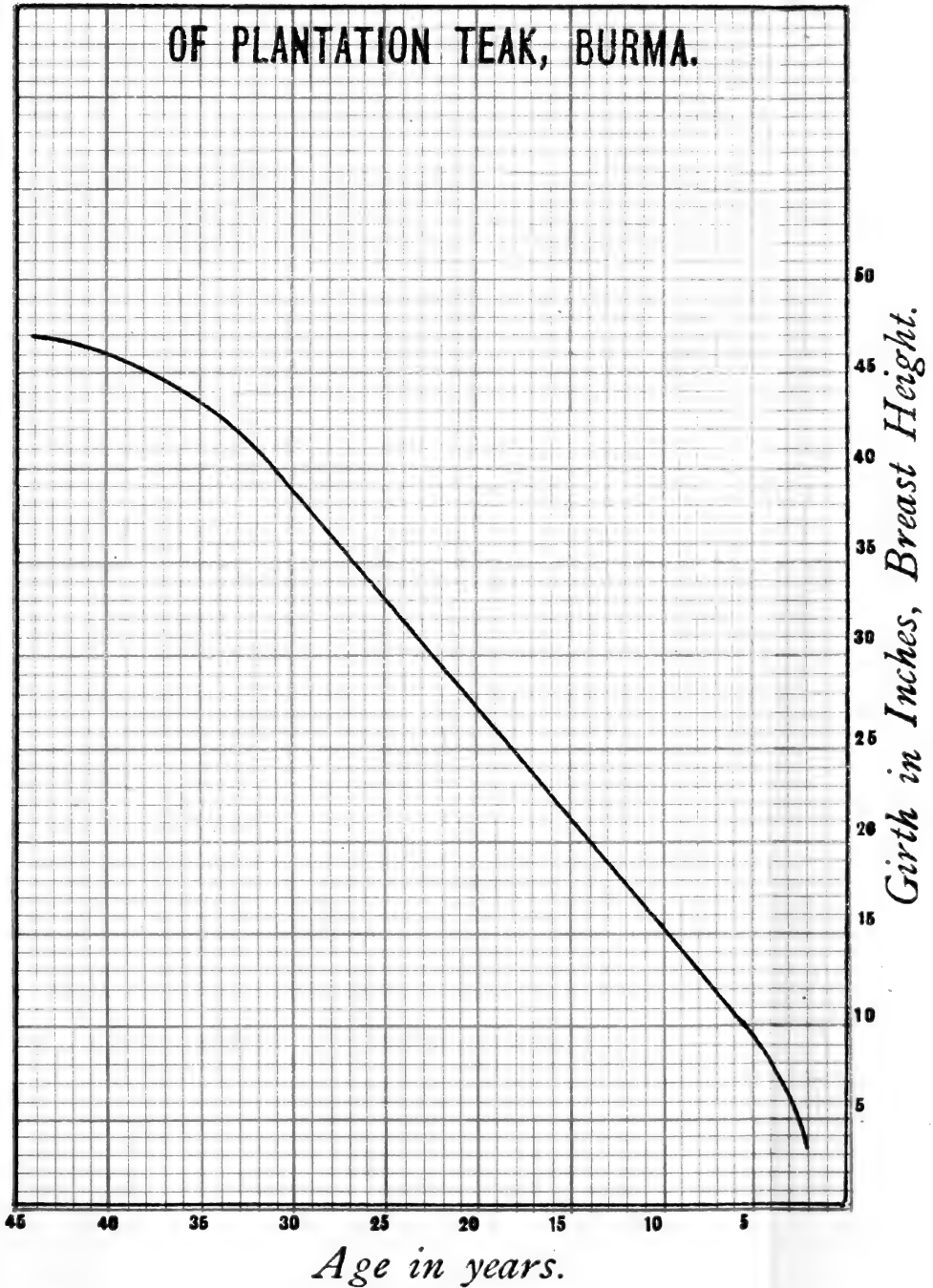
Number of Trees Analysed=41 [1-34 felled in the thinning of March, 1919 and 35-41 felled in May, 1919]. *Date of Analysis*=10th-13th May, 1919.

TABLE 5.—*Girth-Beehole Incidence in an 8-year-old Plantation, Bilumyo, Katha, 1919.*

3 Inch Girth-Class	Serial Number of Sample Tree.	Girth in Inches.	Number of Beeholes.	Arithmetic Mean of Girth-Class.	Arithmetic Mean Beeholes per Girth-Class.
7—9	39	9.75	1	9.75	1.0
10—12	6	12.75	1	11.7	0.25
	13	12.5	0		
	15	10.25	0		
	17	11.25	0		
	1	15.0	0		
	2	13.5	0		
	3	14.25	2		
	7	15.75	0		
	5	15.75	0		
	9	15.0	0		
13—15	10	15.25	1	14.87	0.45
	11	13.75	0		
	12	14.75	0		
	16	13.25	0		
	18	15.75	0		
	19	15.0	0		
	21	14.25	0		
	22	15.75	0		
	24	14.75	0		
	25	15.0	0		
16—18	26	15.5	1	17.0	0.69
	30	14.75	0		
	35	15.0	4		
	40	15.5	1		
	4	16.25	0		
	8	18.0	0		
	14	18.0	0		
	20	17.5	1		
	23	17.25	0		
	27	16.5	0		
19—21	28	16.5	1	20.0	3.0
	29	16.0	0		
	31	17.25	0		
	32	17.5	1		
	33	18.25	0		
Arithmetic Means.	34	16.5	2	15.3	0.59
	36	16.5	4		
	38	20.0	3		
		

By plotting the above means to obtain the girth-beehole curve, the graph value for a girth of 15.3 inches is found to be 0.5 beeholes, and for a girth of 12.5 inches (being Leete's value for an 8-year-old tree) is found to be 0.2 beeholes.

BEESON:- BEEHOLE BORER OF TEAK
 . RELATION BETWEEN AGE AND GIRTH
 OF PLANTATION TEAK, BURMA.



Redrawn from Leete's Forest Bull. No. 2, Diagram iii.

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* Mr. C. G. E. Dawkins, D. F.O., who thinned this plantation in March, 1919, was of opinion that the part of the area in which kaing grass was abundant and which fronted on a regeneration clearing, was the more severely attacked, and that more frequent signs of the borer occurred in scattered saplings in the grassy natural regeneration area than in the plantation. A special plot of 72 trees in the grassy area was examined in May, 1919, by the writer, and a 1918 attack of 8.3 per cent was determined. In the trees felled in the interior, with undergrowth less abundant, the percentage of 1918 attack was 12.5. Mr. Dawkins, however, notes that his impression was influenced by the large proportions of woodpecker holes also observed.

In other parts of the Regeneration Block examined the borer is everywhere conspicuous and is abundant even in two-year old stands; no time was available for surveys.

The annual incidence in the sample plot is given in the following table.

TABLE 6.—*Annual Incidence in an 8-year-old Plantation, Bilumyo, Katha, 1919.*

	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	TOTAL.
Combined Attack, 13 Trees.	2	..	4	4	1	12	23
Reduced Values	0.04	..	0.09	0.09	0.02	0.26	0.5

In the Annual Incidence Graph the values for this sample area are plotted (solid red line) as for a mean tree of 15.0 inches with 0.5 beeholes.

The vertical distribution of the beeholes in this sample plot is given on p. 98 and in Diagram 3.

3. Incidence in Natural Forest.

Mr. Dawkins kindly furnished the following information on the occurrence of beeholes in teak logs extracted from adjoining natural forest [Compartment 2, Coupe A, Billumyo Reserve] in November, 1918 to January, 1919, from girdlings of December, 1915. The beeholes were counted on the sawn ends only, as the logs could not be rolled or barked.

Number of logs examined = 356. Number of logs with beeholes = 115 or 32.3 per cent. Total number of beeholes found = 172. Mean number of beeholes per log = 1.5. Maximum number of beeholes per log = 5.

It was observed that most of the holes were in top logs.

A tree felled by the writer and analysed on 13th May, 1919, gave the following results :—Sample Tree 37 ; Girth=5'—3½"; Age=109 years ; Bole—length billeted=66 feet ; Total Beeholes=33.

TABLE 7.—*Annual Incidence in a 109-year-old Tree, Bilumyo Reserve, Katha, 1919.*

1860	1861—1864	1865	1866—1877	1878	1879	1880	1881—1884	1885	1886—1888	1889	1890—1891	1892	1893	1894	1895	1896	1897	1898	1899
1	0	1	0	1	0	1	0	1	0	1	0	1	1	3	1	3	1	0	1
1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	—
0	1	2	1	1	0	1	0	2	1	4	2	0	1	1	0	0	0	0	

Or if grouped in decades, a preponderance appears in the last three decades, *viz.* :—

1859-1868. 1869-1878. 1879-1888. 1889-1898. 1899-1908. 1909-1918.

2

6

3

10

9

9

This incidence is plotted on the same scale as the sample plot value in the Annual Incidence Graph (in solid black line). As regards vertical distribution of beeholes in this tree a concentration occurs in the middle third of the bole ; *viz.* :—

Height	.	.	0—15'9"	15'9"—31'6"	31'6"—47'3"	above 48'
Number of Beeholes	.	.	7	15	10	1

2. QUARRY SIDING PLANTATION, 1898, MOHNYIN RESERVE.

1. Description of the Sample Plot.

Area of the plantation=4·2 acres ; well-stocked and well-tended in the past. On level ground well-drained. The sample trees were chosen from the whole plantation.

Undergrowth.—In 1915 seeds of *Cephalostachyum pergracile* were sown broadcast over about one acre and *Disoxylum binectiferanum* over another acre. *Bursera serrata* was also sown but failed. On the whole the plantation appears to have possessed a low, sparse undergrowth, in places reaching 6 feet, for most of the period, with a marked scarcity of kaing and thetke grass.

Past History.—Thinned and cleaned in November 1903 ; thinned in August and November, 1906, removing 143 trees per acre ; thinned in November, 1909, removing 120 trees per acre ; thinned in December, 1914, leaving about 260 trees per acre ; trees top-broken by wind of one or two seasons previously were felled in February, 1918.

The plantation was fire-protected up to 1914, but was burnt in 1899, and again in March 1901. From 1914 protection was abandoned, and as the locality is mainly dry forest it was probably burnt over each year.

2. Results of Analysis.

Number of Trees Analysed = 27 [including 5 felled in February, 1918]

Date of Analysis.—15th—24th May, 1919.

The tables below show the relationship of girth to beehole attack in area.

TABLE 8.—*Girth-Beehole Incidence in a 21-year-old plantation, Mohngyin Reserve, Katha, 1919.*

3 Inch Girth-Class.	Serial Number of Sample Tree.	Girth in Inches.	Number of Beeholes.	Arithmetic Mean of Girth-Class.	Arithmetic Mean Beeholes per Girth-Class.
16—18 {	4	16.25	0	17.0	1.0
	18	17.0	2		
	3	17.75	1		
19—21 {	16	20.0	0	19.5	2.0
	17	19.0	1		
	12	19.5	1		
22—24 {	2	19.5	6	23.0	3.5
	14	23.0	5		
	19	23.0	2		
25—27 {	10	27.0	0	25.8	3.25
	23	25.0	5		
	24	25.25	1		
28—30 {	25	26.0	7	29.1	6.7
	5	30.0	15		
	13	29.0	5		
34—36 {	22	28.5	0	35.0	10.5
	21	34.0	9		
	31	36.0	12		
43—45 {	15	44.25	15	44.25	15.0

The arithmetic mean girth of the sample trees is 27.9 inches and the arithmetic mean number of beeholes per tree is 4.5. The girth of a normal 21-year-old tree according to Leete is 27.7 inches ; the sample trees taken, therefore, are sufficiently representative to give a correct girth-beehole value for this plot. Reading from the curve drawn through

the means of the girth-classes, the beehole index for 27·7 inches girth is found to be 5·6.

The five top-broken trees felled in February, 1918 give the following figures :—

TABLE 9.—*Girth-Beehole Incidence in the Same Plantation at 20 years old, 1918.*

3 inch Girth-Class.	Serial Number of Sample Tree.	Girth in inches.	Number of Beeholes.	Arithmetic Mean of Girth-class.	Arithmetic Mean Beeholes per Girth-class.
13—15	8	15·3	0	15·5	0·0
19—21	1	20·5	5	20·5	5·0
25—27	9	25·0	3	25·0	3·0
31—33 {	6	31·0	9	} 31·0	9·5
	7	31·0	10		

The arithmetic mean girth of this group is 24·6 inches and the arithmetic mean number of beeholes per tree is 5·4. As will be seen from the reduction values per annum for the first group of sample trees given in Table 10 below, the index of attack for 1918 is 0·4 beeholes; this would give a beehole value of $5·4 + 0·4 = 5·8$ for this group of trees had they lived a year longer. The close agreement between the indices of attack for the two groups of sample trees shows, that the results are not far wrong. As this degree of infestation is distinctly below the average for trees 21 years old, it is interesting to find that Quarry Siding plantation possesses the reputation of being one of the worst attacked areas in Burma. In 1905 when the plantation was 7 years old, Stebbing estimated that “40 to 50 per cent of the trees in the area inspected showed the present attacks or results of past attacks of the caterpillar.” The Report on Forest Administration, Burma, for 1908-09, page 52 states that “in the Mohnyin Reserve over 10 per cent of the older trees have been attacked and in plantations not more than 20 per cent have escaped.” The Working Plan for the Mohnyin Reserve, 1910, page 6 emphasises the abundance of the borer and the great damage done in Quarry Siding plantation. In 1914 the writer visited this plantation and estimated the current year’s attack at 15 per cent, and pointed out in the Report on the Beehole Borer Enquiry for 1914, that Quarry Siding plantation appeared to possess an undeserved notoriety for beeholing. If the data in Tables 8 and 9 are examined it will be seen that in 1914 only 4 trees out of 24 or 16·6 per cent were attacked, an unexpected confirmation after a lapse of 5 years.

TABLE 10.—*Annual Incidence in a 21-year old Plantation, Mohnyin Reserve, Katha, 1919.*

Serial No. of Tree.	Girth.	1898— 1901.	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	TOTAL.
3	17-75	..	..	..	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
17	19-0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	1
12	19-5	..	..	..	..	..	..	..	..	..	1	2	0	0	0	0	1	0	0	1
2	19-5	..	..	..	..	..	..	..	..	..	1	1	0	0	0	0	0	0	0	6
14	23-0	..	..	..	..	..	1	0	0	1	1	0	0	0	1	0	0	0	1	5
19	23-0	..	..	..	..	..	..	..	..	1	0	0	0	0	0	0	0	0	1	2
23	25-0	..	..	..	..	..	..	..	..	3	0	1	0	1	0	0	0	0	0	5
24	25-25	..	..	..	..	..	..	..	..	..	1	0	0	0	0	0	0	0	0	1
25	26-0	..	1	2	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	7
5	30-0	..	4	0	2	0	0	0	1	1	4	0	0	1	0	0	1	1	1	15
13	29-0	..	..	..	..	..	1	0	0	1	1	1	0	0	1	0	0	0	1	5
21	34-0	..	..	..	..	..	..	..	1	0	0	2	4	0	1	0	0	0	1	9
31	36-0	..	..	..	..	..	..	..	4	0	2	1	1	0	0	1	2	1	0	12
15	44-25	..	..	..	..	..	1	0	2	0	7	0	0	0	3	0	2	0	0	15
TOTAL.	..	..	5	2	4	1	3	0	8	7	17	7	5	2	6	2	7	3	6	85
REDUCED VALUES.	..	..	0-3	0-1	0-3	0-05	0-2	0-0	0-5	0-5	1-1	0-5	0-3	0-1	0-4	0-1	0-5	0-2	0-4	5-6
9	25-0	..	..	..	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3
1	20-5	..	..	..	..	..	..	..	3	3	1	1	0	0	0	0	0	0	0	5
6	31-0	..	..	..	..	..	1	0	0	1	2	0	3	1	0	1	0	0	0	9
7	31-0	..	..	..	3	3	0	0	0	0	0	0	0	0	0	1	2	1	1	10
TOTAL	..	..	..	..	4	3	1	0	2	4	3	1	3	1	0	2	2	1	1	27
REDUCED VALUES.	..	..	..	..	0-8	0-6	0-2	0-0	0-4	0-8	0-6	0-2	0-6	0-2	0-0	0-4	0-4	0-2	0-4	5-4

The last 4 trees, Nos. 9, 1, 6 and 7 are top-broken trees felled in 1918; plotted separately the general trend of the annual incidence curve agrees with that for the 19 trees felled in May, 1919. The data for the latter reduced to a mean total attack of 5.6 beeholes per tree, is plotted in the Annual Incidence Chart in a solid red line.

The vertical distribution of beeholes in trees in this plot is given on p. 98 and in Diagram 3.

3. INCIDENCE IN NATURAL FOREST, MOHNYIN RESERVE.

1. Description of Sample Plot.

Close to the plantation is a patch of pure teak of several acres extent, consisting of trees 45 years old and over, and trees about 26 years old. The latter appear mainly to be coppice shoots and probably originated from clearings made along the line of the railway in 1891-92; in 1893 the railway was open to Mohnyin, several miles above the site of the plots. Ring countings on the stumps of the sample trees gave 23 to 28 rings, but it is probable that the fellings all took place about the same time.

Underwood.—The principal trees and shrubs mixed with the teak are *Bursera serrata*, *Terminalia chebula*, *Gmelina arborea*, *Phyllanthus*

pomiferus, *Alstonia scholaris*, *Disoxylum binectiferanum*, *Stephygyne parviflora*, *Sterculia* sp. and *Anogeissus acuminata*. Herb and grass growth is fairly abundant; bamboos are absent.

Past History.—The forest was very little worked in Burmese times except locally for the requirements in teak of the villages of Mohnyin and Mogaung. Girdlings and clearings occurred along the line of the railway in 1891-92 and their effect on the area sampled has been mentioned above. In 1899-1900 and again in 1904-05 teak girdlings were carried out in the forest nearby.

Fire protection was in force and fairly successful during the period 1895-1910 [W. P., Mohnyin Reserve, p. 4] and completely successful during the period 1900-1910 [W.P., p. 8]. Block V, which contains the areas sampled, has been protected up to 1914, while the surrounding forest was departmentally burnt annually from 1910. Since 1914 the area under consideration has probably been burnt each year.

2. Results of Analyses.

Number of trees Analysed=15. *Date of Analysis*=15th-24th May, 1919.

TABLE 11.—*Girth-beehole incidence in Natural Forest, Mohnyin Reserve, Katha, 1919.*

3 Inch Girth-Class.	Serial Number of Sample Tree.	Approximate Age.	Girth in Inches.	Number of Beeholes.	Arithmetic Mean of Girth-Class.	Arithmetic mean Beeholes per Girth-Class
16—18 {	32	23	16.0	10	} 16.5	7.5
	38	24	17.0	5		
	36	23	19.0	0		
19—21 {	34	25	19.5	12	} 19.5	5.0
	35	23	20.0	3		
22—24 {	33	24	22.5	18	} 23.0	12.0
	28	44	23.5	6		
25—27 {	39	29	25.0	17	} 26.0	18.0
	40	28	26.0	12		
	26	42	27.0	25		
28—30 {	27	26	30.0	35	} 30.0	34.5
	20	37	30.0	34		
31—33 {	29	54	33.5	24	} 33.5	24.0
37—39 {	37	58	37.0	45		

It is probable that the figures given for the ages are in most cases underestimated, but the sample trees can be arranged in two fairly well-defined groups of 5 each, in order to arrive at the index of attack. Sample trees Nos. 38, 34, 35, 33 and 27 have a mean girth of 21.0 inches, and a mean age of 24.4 years, and an arithmetic mean number of beeholes of 13.6. On the girth-beehole graph plotted from the data in Table 11, the beehole value for a 21.0 inch tree is 9.6. This figure is taken as the

index of attack for the 23-26 year old trees. Sample Trees Nos. 28, 26, 20, 29 and 37 have a mean girth of 30.2 inches, and a mean age of 47, and a mean number of bee-holes of 26.6. The bee-hole-girth curve gives a graphical value of 22.0 bee-holes for a 30.2 inch tree. This value is taken as the index of attack for trees forming the older part of the stand. Making allowance for the difference in age it would appear that the natural forest trees are quite as badly attacked as the plantation trees.

With regard to the annual distribution of the borer attack in this area three graphs have been prepared, one for the plantation trees 21 years old, the second for natural forest trees approximately 25 years old and the third for natural forest trees with a mean age of 47 [see Annual Incidence Graphs]. The constant parallelism in the behaviour of the three curves is striking and indicates that the dating of the bee-holes is free from serious errors.

TABLE 12.—*Annual Incidence in Natural Forest, Mohynin Reserve, Katha, 1919.*

Total Attacks	5	12	3	15	33	68	9.6	6	24	34	24	45	133	22.0
1918	1	1	0	1	3	6	0.8	0	2	1	1	3	7	1.2
1917	0	1	0	0	1	2	0.3	0	0	0	0	2	5	0.3
1916	1	3	0	1	0	5	0.7	0	0	3	0	2	5	0.8
1915	0	3	0	1	2	6	0.8	0	1	1	1	1	4	0.7
1914	0	0	0	0	4	4	0.6	0	1	3	1	3	8	1.3
1913	0	0	0	3	1	4	0.6	0	0	0	0	1	1	0.2
1912	3	0	0	2	3	8	1.2	0	0	4	0	2	6	1.0
1911	..	2	0	2	3	7	1.0	1	5	0	2	5	13	2.1
1910	..	0	9	1	8	9	1.2	0	0	4	3	4	11	1.8
1909	..	0	0	1	3	4	0.6	0	0	3	0	1	4	0.7
1908	..	0	0	0	1	1	0.1	0	0	1	1	1	3	0.5
1907	..	1	0	0	0	1	0.1	0	0	0	1	1	2	0.3
1906	..	1	0	0	0	1	0.1	0	3	3	0	0	6	1.0
1905	..	0	1	0	1	2	0.3	0	0	1	0	0	1	0.2
1904	..	0	0	0	0	0	0.1	0	0	4	0	3	8	1.3
1903	..	0	0	0	1	1	0.1	1	0	0	0	1	1	0.2
1902	..	1	0	1	0	1	0.3	0	1	1	0	0	2	0.3
1901	..	..	0	0	1	2	0.3	0	1	0	0	0	3	0.5
1900	..	..	2	0	0	2	0.1	1	0	1	4	3	8	1.3
1899	..	..	..	0	1	1	0.0	0	1	1	1	1	5	0.8
1898	..	..	..	0	..	0	0.3	1	5	3	2	3	13	2.0
1897	..	..	..	2	..	2	..	0	4	..	1	1	6	1.6
1896	..	..	..	..	..	..	..	0	..	..	2	4	6	1.0
1895	..	..	..	..	..	..	..	0	..	..	0	0	2	0.3
1894	..	..	..	..	..	..	..	2	..	..	0	0	0	0.0
1893	..	..	..	..	..	..	..	..	..	..	0	0	0	0.0
1892	..	..	..	..	..	..	..	..	..	..	0	0	0	0.0
1891	..	..	..	..	..	..	..	..	..	..	0	0	0	0.0
1890	..	..	..	..	..	..	..	..	..	..	0	0	0	0.0
1889	..	..	..	..	..	..	..	..	..	..	0	0	0	0.0
1888	..	..	..	..	..	..	..	..	..	..	1	2	3	0.5
1887	..	..	..	..	..	..	..	..	..	..	1	0	1	0.2
1886	..	..	..	..	..	..	..	..	..	..	0	0	0	0.0
1885	..	..	..	..	..	..	..	..	..	..	1	0	1	0.2
1881-1884	..	..	..	..	..	..	..	..	..	..	..	0	0	0.0
1880	..	..	..	..	..	..	..	..	..	..	..	1	1	0.2
1861-1879	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Age in Years	24	25	23	24	26	TOTALS.	REDUCED VALUES.	44	42	37	54	58	TOTALS.	REDUCED VALUES
Girth in Inches	17	19	20	22	30			23	27	30	33	37		
Serial No. of Sample Tree	38	34	35	33	27			28	26	20	29	73		

The data in the above table are so arranged as to obtain a comparison of the attack on young trees and the attack on old trees. Both groups show similar annual fluctuations and in this the plantation trees also agree. The intensity of annual attack on the older trees does not increase with age but on the contrary shows periodic increases and decreases, the maxima of which are slightly more than the maxima in the younger trees and in the plantation. The sudden recrudescence in 1895 is rather striking, and may be connected with the fellings in 1891-92 or with the commencement of fire-protection in 1895.

The vertical distribution of beeholes in this area is discussed on pp. 98, 99 and shown in Table 35 and Diagram 3.

In other parts of Mohnyin Reserve plantations made in the last 10 or 15 years are badly infested by the borer. A mixed plantation made in 1914 of Teak, *Gmelina arborea*, *Bursera serrata*, *Cedrela Toona* and other species in rows, was especially examined for beehole borer. Although teak in many places has been ousted by the other species in the mixture, and is not numerically abundant, it is severely attacked, and appears to have derived no protection from the presence of other tree species.

4. PLANTATION NO. 2 OF 1897, PETSUT RESERVE.

1. Description of Sample Plot.

In a plantation of 12·0 acres, on a gentle slope of south aspect in hilly country ; soil a strong loam, free from stones. Growth very variable, on the lower slopes good and well-stocked but in places higher up the slope very poor and much suppressed.

Undergrowth.—Very variable, in places dense clumps of *Bambusa Tulda* and climbers, elsewhere a low underwood of small shrubs. Sample trees were chosen with particular reference to undergrowth and detailed notes are given below.

Past History.—Light thinning in August, 1904 ; thinning in February, 1907, August, 1912 and December, 1916. With regard to fires, Mr. A. W. Moodie, D. F. O., informs me that in 1899 a fire occurred over half the area burning back the young plants. In 1914-15 the forest near the plantation was burnt and it is extremely probable that the plantation was also affected. With the exception of the fires the whole reserve was fire-protected from 1897-1914, and the plantations up to 1914-15. From 1914-15 to 1916-17 fire protection was abandoned, and fires almost certainly occurred in the area. From 1917-18 to date early departmental burning has been carried out.

2. *Results of Analyses.*

Number of Trees Analysed=19. *Date of Analysis* 3rd-8th June, 1919.

TABLE 13.—*Girth-Beehole Incidence in a 22-year-old Plantation, Petsut Reserve, Katha, 1919.*

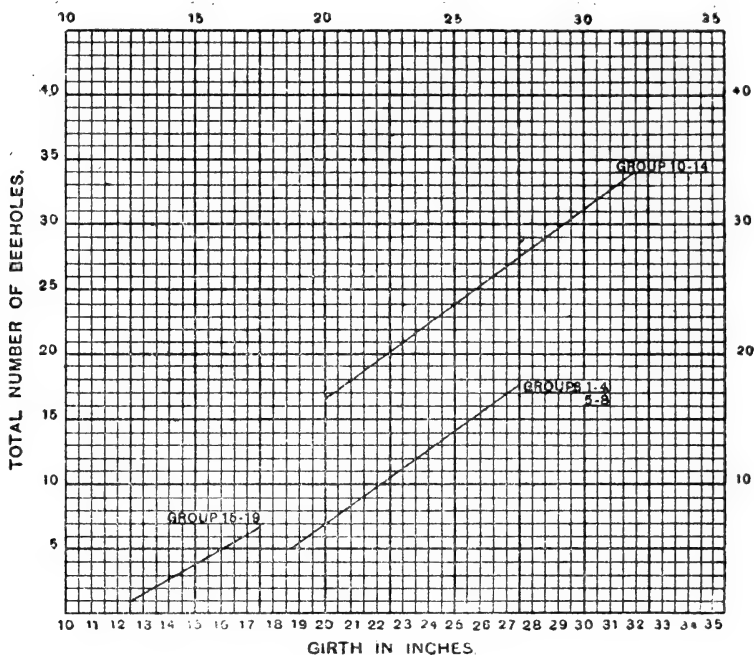
3-inch Girth-Class.	Serial Number of Sample Tree.	Girth in Inches.	Number of Beeholes.	Arithmetic Mean of Girth-Class.	Arithmetic mean Beeholes per Girth-Class.
10—12	18	11.0	0	11.7	0.5
	16	12.5	1		
13—15	19	13.75	3	14.1	2.0
	17	14.25	1		
16—18	2	16.5	8	17.3	7.2
	15	17.0	6		
	12	18.5	7		
19—21	10	19.0	3	19.7	14.7
	8	19.5	13		
	9	20.0	17		
	13	20.5	26		
22—24	11	22.0	30	23.6	16.3
	6	24.0	12		
	3	24.75	7		
25—27	4	25.0	20	25.1	14.0
	7	25.0	7		
	5	25.25	15		
28—30	1	28.0	12	28.0	12.0
31—33	14	32.0	34	32.0	34.0

The arithmetic mean girth of the sample trees is 21.4 inches and the arithmetic mean number of beeholes is 11.0. The girth of the mean normal tree 22 years old is 29.0 inches and the graph value in beeholes for this girth is 21.5. To counterbalance the effect of the abnormally slow-grown sample trees, the average between the arithmetic mean girth of the sample trees and the girth of Leete's normal tree is taken for the index of attack in the plantation, viz., $\frac{29 + 21.4}{2} = 25.2$ inches. The graph value for this girth is 16.25 beeholes, which is also the arithmetic mean of the two figures obtained above, viz., $\frac{21.5 + 11}{2} = 16.25$ beeholes. This figure indicates a fairly high degree of attack.

Effect of undergrowth.

The sample trees were chosen in small groups with different types of undergrowth to see if there is any appreciable connection between the density of the underwood and the degree of attack. The girth-beehole

incidence for the different groups is shown in the accompanying graph.



COMPARISON OF INCIDENCE BY GROUPS, PETSUT, KATHA,
1897.

Group 1—4. On the slight slope below the following group, in a belt without bamboos and with undergrowth more scanty or more thoroughly cut back.

Tree No. 1, 28," BH. 12, codominant; undergrowth scanty; a few bamboos nearby; creepers abundant.

Tree No. 2, 16½," BH. 8, suppressed; undergrowth rather more scanty and cut back; climbers abundant; bamboos distant.

Tree No. 3, 24¾," BH. 7, dominant; stem thickly girt with creepers; undergrowth scanty and cut back; bamboos distant.

Tree No. 4, 25", BH. 20, dominant; as above but only slight creeper growth.

Group 5—8. In a zone higher up the slope than 1—4; height growth and general development much poorer; chosen mainly as less vigorous trees, that have had to contend with bamboos.

Tree No. 5, $25\frac{1}{4}$ ", BH. 15, dominant; bamboos around but not high, nevertheless reaching to crown.

Tree No. 6, 24", BH. 12, dominant; bamboos not dense, but one high bamboo on one side.

Tree No. 7, 25", BH. 7, free crown, but crippled and bent; surrounded by bamboos.

Tree No. 8, $19\frac{1}{3}$ ", BH. 13, free-standing, bamboos all round.

In group No. 1-4 the mean girth is 23·5 inches and the mean number of beeholes is 11·7. In group 5—8 the mean girth is 23·4 inches and the mean number of beeholes is 11·7. The incidence of the two groups is therefore identical, and the influence of bamboos is *nil* or not appreciable.

Group 9—14. Higher up the slope with abundant undergrowth and bamboos, and poor height growth.

Tree No. 9, 20", BH. 17, free-standing; bamboos low and undergrowth present, but the tree stands well in the open.

Tree No. 10, 19", BH. 3, dominant; height growth very much poorer; undergrowth denser and higher.

Tree No. 11, 22", BH. 30, dominant; height growth as No. 10; bamboos all round, shrubs dense.

Tree No. 12, $18\frac{1}{2}$ ", BH. 7, as above; bamboos abundant to the exclusion of shrubs.

Tree No. 13, $20\frac{1}{2}$ ", BH. 26, as above; surrounded by bamboos and shrubs.

Tree No. 14, 32", BH. 34, dominant; undergrowth abundant and bamboos nearby.

The general incidence in this group is much higher than elsewhere.

Group 15—19. Higher than the previous groups on poorer soil; all small trees, that have been checked by competition with bamboos and shrubs and not by suppression of their own species. Crowns recently freed by thinning and cutting back of bamboos. No big teak in this area; chosen to see if dense undergrowth impedes oviposition.

Tree No. 15, 17", BH. 6.

Tree No. 17, $14\frac{1}{3}$ ", BH. 1.

Tree No. 16, $12\frac{1}{2}$ ", BH. 1.

Tree No. 18, 11", BH. 0.

Tree No. 19, $13\frac{3}{4}$ ", BH. 3.

The conclusions drawn from these data are given below:—

1. The presence of bamboos and shrub undergrowth does not reduce oviposition; on the contrary in two groups (*a*) without bamboos, and (*b*) with bamboos it is the same, and in (*c*) with bamboos and shrubs, it is highest, and in (*d*) where bamboos are densest it is intermediate.

2. The incidence is relatively higher on the upper and steeper slopes than in lower and less steep slopes.
3. Girth is a far more dominant factor than undergrowth.

Annual Incidence.

Owing to the short time at my disposal only 5 trees could be dated, of which one was rejected.

TABLE 14.--*Annual Incidence in a 22-year-old-Plantation, Petsut Reserve, Katha, 1919.*

Serial number of sample trees.	girth in inches.	1897-1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	TOTAL
5	25-25	..	1	3	0	1	1	2	0	5	1	0	0	1	0	0	0	0	15
6	24-0	..	..	..	..	..	..	3	1	1	0	5	0	1	0	1	0	0	12
8	19-5	..	..	1	1	0	0	1	3	1	0	1	0	2	0	1	0	2	13
9	20-0	..	..	..	..	..	..	..	4	0	2	2	0	0	1	1	0	7	17
TOTAL	.	..	1	4	1	1	1	6	8	7	3	8	0	4	1	3	0	9	57
Reduced Values.		..	0.3	1.1	0.3	0.3	0.3	1.7	2.3	2.0	0.9	2.3	0.0	1.1	0.3	0.9	0.0	2.6	16.2

The curve of annual incidence for these 4 trees is plotted in the chart for a mean tree containing 16.25 beeholes. While the total attack which is based on 19 trees, is approximately correct the annual fluctuations are probably not representative of local conditions.

The vertical distribution of beeholes in these sample trees is shown in Diagram 3 and Table 35, p. 98.

Other Localities in Petsut Reserve.

In 1908 the beehole borer was found by the Divisional Forest Officer in the Dobin Chaung Plantation of 1898. In December, 1910 and January, 1911, and again in August, 1912 larvae of the beehole borer were found plentifully in several plantations thinned by Mr. J. W. Bradley, Assistant Conservator of Forests.

In a general note on the Nankan Plantations by Mr. A. E. Elmore in February, 1909, reference is made to the abundance of the beehole borer and an attempt was made to estimate the proportion of beeholed trees in the thinned material.

With regard to the Nami Plantations Mr. Elmore records in November, 1919, that all plantations have been more or less attacked and notes

the presence of larvae $\frac{1}{2}$ " to 2" long. In December 1916 beeholes were observed everywhere "even in the healthy trees."

The writer visited this reserve in April, 1914, and carried out a few enumerations in Plantations No. 2 of 1897 and Nos. 11 and 12 of 1900 to determine the abundance of the borer from the evidence of emergence holes and partly healed beeholes in the standing tree. The following statement gives the results obtained, in plots of roughly one acre each :—

TABLE 15.—*Incidence in Plantations, Petsut Reserve, Katha, 1914.*

Appearance of the Beehole.	PERCENTAGE OF SAMPLE TREES.		
	*Plantation 2 of 1897.	Plantation 11 of 1900.	Plantation 12 of 1900.
1. Fresh emergence holes	6	1	3
2. Old non-occluded holes or overgrown holes with evident scars.	22	5	10
3. Trees without external signs of attack.	72	94	87

The trees were examined up to the crown branches by climbing or with field-glasses, but there is a strong probability that many holes were missed and that the incidence of attack is higher than appears from the figures.

2. Sample plot in Shwegu Subdivision, Bhamo.

1. BEEHOLE BORER OBSERVATION AREA, OKKYI, LOWER KYAUKKWE.

1. *Description of the Sample Plot.*

Mr. A. R. Villar, who was placed on special duty in April, 1916, in connection with the beehole borer investigations, selected a plot on the right bank of the Kyaukkwe stream, near Okkyi, Shwegu subdivision, and enumerated the attacked trees, surveyed the area and maintained observations until the end of May. The data in his report are given below together with information on the botany and past history of the area furnished by Mr. A. J. Butterwick.

Situation.—The plot (area about 2 acres) is part of a patch of almost pure natural teak situated on the flat top of an isolated knoll surrounded

on all sides by dense evergreen forest known as "Myaingtaw." From June to September the evergreen jungle is flooded to a depth of 4-7 feet, leaving the patch of teak as an island. *Soil* a reddish clayey-loam, badly eroded. *Stand.* The predominant species in the Myaingtaw are *Xanthophyllum flavescens*, *Elaeocarpus grandiflorus*, and *Coccoceras plicatum*. In the sample plot teak forms about 90 per cent of the crop; the trees vary in age and in girth from 1' to 5', with a few trees of *Albizia procera*, *Miliusa velutina*, *Wrightia tomentosa*, *Derris robusta*, *Homalium tomentosum*, *Cratoxylon prunifolium*, *Vitex* sp. and *Grewia* sp.

Undergrowth very sparse, principally of *Clerodendron*, thetke and canes, and annual shoots of the following climbers, *Acacia pennata*, *Harrisonia Bennettii*, *Dalbergia volubilis*, *Spatholobus Roxburghii* and *Dioscorea* sp., Bamboos absent.

Past History.—The past history of the forest is difficult to ascertain. The neighbouring Wapyudaung Reserve was notified and settled between 1909 and 1913. Most of the riverine villages are of recent origin, but taungya-cutting families were settled near the plot at least 20 years ago (one of the trees analysed bears *dah* cuts made in 1885 at 3 feet above ground).

It is probable that the patch of teak and several similar patches originated on abandoned cultivation. The trees analysed are mainly about 42 years old, some obvious stool shoots, but the larger trees are much older. As regards fires local tradition says that the area was originally covered with dense grass growth, but annual fires have destroyed it, and reduced the shrubs and climber growth to a negligible quantity. Annual fires have certainly occurred for many years past and have been accompanied by heavy denudation. Some of the logs cut on sloping ground by Mr. Villar in April, 1916, lay nearly an inch above the surrounding soil in June, 1919.

1916. In 1916 emergence holes were located at heights up to 55 feet on 87 trees out of 998 in the plot. The distribution of the attack was not uniform, but occurred in 3 areas of different intensity, *viz.*:—

Section.	Trees with Emergence Holes.	Total Number of trees.	Percentage of Trees Attacked.
1	27	185	14.6
2	5	330	1.5
3	52	483	10.76
Whole Area	84	998	8.4

(Trees Nos. 84, 86 and 87 showing signs of attack but outside the area after demarcation are not included). There was apparently no difference in the nature of the stand or of the undergrowth in the 3 sections.

1919. The writer worked in this area at the end of May, 1919, and carried out analyses of trees felled in the sample plot.

Number of Trees Analysed—19. *Date of Analysis*—28th May—2nd June 1912.

The following table 16 gives the data for the girth-beehole incidence, and the approximate ages of the trees :

TABLE 16.—*Girth-Beehole Incidence in Natural Forest, 31—46 years old Okkyi, Shwegu, 1919.*

3-Inch Girth-Class.	Serial Number of Tree.	Girth in Inches.	Approximate Age.	Number of Beeholes.	Arithmetic Mean of Girth-Class.	Arithmetic mean Beehole per Girth-Class.
10—12	14	11.75	16	4	11.75	4.0
16—18	5	16.0	39	10	16.0	10.0
19—21	2	21.0	42	40	20.3	21.7
	8	20.0	38	11		
	10	20.0	40	14		
25—27	7	26.75	41	5	25.8	12.3
	16	25.5	42	23		
	18	25.25	31	9		
31—33	4	32.0	42	71	32.0	58.0
	12	32.0	39	45		
	1	36.0	42	31		
34—36	6	36.75	47	80	35.4	45.7
	11	34.25	40	22		
	13	34.5	35	50		
37—39	9	39.75	48	38	38.7	41.7
	15	37.5	35	48		
	19	39.0	42	39		
40—42	3	40.0	42	23	40.7	31.5
	17	41.5	31	40		

It will be observed that there is a much greater variation in the number of beeholes per tree, in this group of uneven-aged trees, than in a plantation, and also that the means for the girth-classes do not form a steady series. One of the youngest trees, for example, No. 17, has the greatest girth and a high number of beeholes. The derivation of an index of attack for this area must, therefore, be largely arbitrary.

The arithmetic mean girth of the sample trees is 27.6 inches, the arithmetic mean number of beeholes is 31.7, and the arithmetic mean age

(excluding tree No. 14) is 39·8 years. Plotted as a girth-beehole graph the data in Table 16 give a rather steep curve [See Girth-Beehole Incidence Graphs], but its upper limits fall between those for the Pyonchaung plantations of comparable ages, and it may be accepted as approximately correct. Of the 603 beeholes examined only 258 are definitely dateable; the mean age of the dateable trees is 40 years and their mean girth 36 inches. The beehole-value for a girth of 36 inches is 42. The mean girth of the trees 40-42 years old (containing 140 beeholes) is 34·4 inches and the beehole value derived from the curve is 39. The index of attack in this area is therefore between 39 and 42 beeholes in the mean tree.

Annual Incidence.

A large proportion of the sample trees was found after billeting to show zones of suppression at various periods, and accurate dating of only 42·8 per cent of the beeholes was possible. The following table shows the annual frequency of the attack in the 7 dateable trees :—

TABLE 17—Annual Incidence in Natural Forest 31—47 years old, Okkai, Shwegu, 1919.

Serial No. of Tree, Approximate Age, Girth in inches, 1872-81	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	TOTALS.		
3 42 40	1 0 0 0	0 1	0 2 1	0 2 1	1 1 1	1 1	2	1	2 3	1 1	1 1	2	1	2 3	1 1	1 1	1 1	1 1	1 1	1 1	2	1	2 3	1 1	1 1	1 1	1 1	1 1	0 3	20	23	
4 42 32	1	0 0 0	0 0 1	0 0 1	0 0 1	0 0 1	1 0 0	1 1 3	2 3 2	3 6 5	6 7	2	2 3	6 6	1 4	3 2	2 3	2 3	6 6	1 4	3 2	2 3	6 5	6 7	2 3	2 3	6 6	1 4	3 2	2 3	6 6	1 4	3 2	2 3	2 3	71	71	
6 47 36 1/2	1	0 0 0	0 0 1	0 0 0	0 0 1	0 0 0	0 0 1	0 0 0	1 0 0	0 3 8	9 12 3	3 2	0	1 3	6 5	1 0	4 1	11 78	0	1 3	6 5	1 0	4 1	11 78	0	1 3	6 5	1 0	4 1	11 78	0	1 3	6 5	1 0	4 1	11 78	0	4	4	
7 41 26 1/2		
11 40 34 1/2	1 0 0	0 0 1	2 0 1	2 2 3	0 1	2 1	1 1	0 0	1 0	2 1	1	2 1	1 1	0 0	1 0	2 1	1 1	0 0	1 0	2 1	1	2 1	1 1	0 0	1 0	2 1	1 1	0 2	21	21		
17 31 41	1 1 0	3 0 0	0 0 2	3 2	4	6	1 1	2 4	1 3	4 2	4	6	1 1	2 4	1 3	4 2	4	6	1 1	2 4	1 3	4 2	4	6	1 1	2 4	1 3	4 2	4	40	40	
19 42 39	2 1 1	2 2 0	1 2 3	0	1	2 3	0 1	2 3	0	1	2 3	0 1	2 3	0	1	2 3	0	1	2 3	0	1	2 3	0 1	2 3	0	1	2 3	0	3	21	21
TOTALS	1	1	1	0 0	1 0	2 2	1 0	0 0	2 2	4 3	13 12	17 21	14 20	15	9	13 14	17 12	10 6	13	7	24 258																			
Reduced Values.	..	0.2	0.0	0.2	0.0	0.0	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.3	0.6	0.5	2.1	2.0	2.7	3.4	2.3	3.2	2.4	1.5	2.1	2.3	2.7	2.0	1.6	1.0	2.1	1.1	3.9	42		
Trees 41-42 only.	1	0 0	1 0	1 1	1 0	0 0	1 1	0 3	7 4	8 9	9	14	11	5	6	10	10	5	5	5	6	2	11 140															
TOTALS	0.3	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.8	1.9	1.1	2.2	2.5	2.5	3.9	3.0	1.4	1.7	2.8	2.8	1.4	1.4	1.4	1.6	0.5	3.0	39		
Reduced Values.	0.3	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.8	1.9	1.1	2.2	2.5	2.5	3.9	3.0	1.4	1.7	2.8	2.8	1.4	1.4	1.4	1.6	0.5	3.0	39		

In the Annual Incidence Chart the annual frequency is plotted in curves for two groups of trees, *i.e.*, Trees 31-47 years old, in solid black line, on a total of 42 beeholes in the mean tree, and Trees 40-42 years old, in solid red line, on a total of 39 beeholes in the mean tree. There is sufficient consonance between the two incidence curves to show, that in this area at least, small groups of sample trees give a fairly accurate idea of the local abundance of the borer.

The vertical distribution of the beeholes in the sample trees in this area is recorded on p. 98. (*Vide* Table 35 and Diagram 3.)

3. Sample Plots in Pyinmana Division.

I. PLANTATION NO. 7 OF 1901, KAING RESERVE.

1. Description of Sample Plot.

At the south-west corner of the plantation No. 7, Mohnit, in and near Burma Forest School Sample Plots Nos. 15 and 16, partly on the valley-floor of a small stream and partly on the terrace-slope alongside. The original area of the plantation was 52 acres, but within its limits, especially in the badly drained places, teak has disappeared or is of poor suppressed growth. On the slopes the growth and stocking is much better, but in the last few years the soil has been heavily eroded.

Undergrowth.—On the valley-flat dense undergrowth of Kaing grass, *Clerodendron* sp., an acanthaceous shrub, a scandent *Acacia*, and other climbers with occasional trees of *Kydia calycina*, *Premna*, sp., *Albizzia stipulata*, etc.; on the slope the undergrowth is replaced by tinwa (*C. pergracile*) and miscellaneous tree species are absent.

Past History.—Weeded 1902-1905; cleaned 1906-1908; thinned in part by the Burma Forest School in August 1915, and completed in August 1916. Fire-protected continuously up to 1911 and from 1912 burnt departmentally each year. Fire protection was not successful in 1903, 1905 and 1911, when the plantation was accidentally burned. The first two fires were extensive, involving nearly the whole of Kaing Reserve.

2. Results of Analyses.

Number of Trees Analysed—7. *Date of Analysis*—1st-3rd May, 1919.

TABLE 18.—*Girth-Beehole Incidence in an 18 year-old Plantation, Kaing Pyinmana, 1919.*

3 Inch Girth-Class.	Serial No. of Sample Tree.	Class.	Girth in Inches.	Number of Beeholes.	Arithmetic mean of Girth-Classes.	Arithmetic mean Beeholes per Girth-Class.
19—21	10	s	19	0	...	...
	12	D	20	2	20.0	1.0
	15	d	20	0	...	...
	13	d	21	2	...	...
22—24	16	d	23	2	23.0	2.0
25—27	14	D	27	6	27.0	6.0
28—30	11	d	28	2	28.0	2.0

The position of the trees does not appear to produce marked differences in the incidence of attack. Nos. 10, 11, 12 were on the badly drained valley-flat, 13 and 14 on the slope and 15 and 16 at the junction of the flat and the slope.

The arithmetic mean girth of the sample trees is 22.57 inches ; the arithmetic mean number of beeholes per tree is 2.0 ; the girth of a normal mean tree 18 years old is 24.25 inches, and the number of beeholes for this tree obtained from the girth-beehole graph is 2.5. This index of attack indicates an infestation slightly less than the average for all sample plots.

The annual incidence is given in the following table.

TABLE 19.—*Annual Incidence in an 18 year-old Plantation, Kaing, Pyinmana, 1919.*

	1901—1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	Total.
Combined attack 7 trees.	0	1	1	3	1	1	0	1	2	1	2	1	14
Reduced values.	0	0.18	0.18	0.53	0.18	0.18	0.00	0.18	0.36	0.18	0.36	0.18	2.5

These data are plotted in the annual incidence graph as those of a mean tree of 24.25 inches girth with a total of 2.5 beeholes. It will be seen that the incidence remains practically level and is not visibly affected by fires or by thinnings. This plantation and the next, No. 5 of 1899, were examined at the suggestion of Mr. L. C. Davis, Divisional Forest Officer, that they might possibly contrast the effects of fire-protection and departmental burning.

2. PLANTATION NO. 5 OF 1899, KAING RESERVE.

1. Description of Sample Plot.

At the north-west corner of the plantation, near the Burma Forest School Sample Plot No. 11. The plantation (56 acres) is on the valley-flat and slopes of the same small stream as in the preceding plantation, but is still more cut up into small patches by the intrusion of Kaing grass, shrubs and bamboos. (An inspection note of 1910 states that fully half should be written off.) The area from which sample trees were taken is in an isolated block surrounded by dense grass and shrub growth and high clumps of *Bambusa polymorpha*.

Undergrowth.—At present, owing to a thinning, low, but previously high shrubby growth, which suppressed much of the teak early in the life of the plantation and caused the remainder to develop forked stems and low branching crowns.

Past History.—Weeded 1900-1905; cleaned 1906-07; thinning and cutting back of bad trees in March 1912; thinning in February 1919. Fire protected up to 1911; burned departmentally 1912-1917. In 1903, 1905 and 1911 accidental fires occurred.

2. Results of Analyses.

Number of Trees Analysed—9. *Date of Analysis*—29th-30th April, 1919.

The trees were felled in February, 1919 in the thinning carried out in this plantation.

TABLE 20.—*Girth-Beehole Incidence in a 20 year-old Plantation, Kaing Reserve, Pyinmana, 1919.*

3 Inch Girth-Class.	Serial Number of Sample Trees.	Girth in Inches.	Number of Beeholes.	Arithmetic mean of Girth Class.	Arithmetic mean Beeholes per Girth Class.	Combined.
16—18 .	3	16	0	16.0	0.0	...
19—21 {	7	19	2 }	19.5	2.5	1.5
22—24 {	4	20	3 }	22.0	1.0	for
25—27 .	5	22	1	27.0	0.0	22"
31—33 {	2	27	0	31.0	12.0	9.3
34—36 {	9	31	12 }	34.0	4.0	for
	6	31	12 }			32"
	1	34	4			

The arithmetic mean girth of the sample trees is 25 inches, and the arithmetic mean number of beeholes per tree is 4.25. Owing to the great variation in the values for the girth-classes it is necessary to combine

them in order to obtain points for the construction of the girth-beehole curve. The girth of a typical mean 20 year-old tree is 26·7 inches and the beehole index for a tree of this girth according to the curve is 4·2 ; as this amount is supported by the figure for the arithmetic mean, this value may be taken as approximately correct. It is slightly below the average for plantations of this age.

The following table gives the annual incidence in the dateable trees.

TABLE 21.—*Annual Incidence in a 20 year-old Plantation, Kaing Reserve, Pyinmana, 1919.*

	899—1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	Total.
Combined Attack, 6 Trees . . .	0	1	..	1	..	4	2	..	3	4	4	3	2	2	1	7	34
Reduced values .	..	0·13	..	0·13	..	0·52	0·26	..	0·29	0·52	0·52	0·39	0·26	0·26	0·13	0·92	4·2

Although the past history of this plot and the previous plot with reference to fires and thinnings is similar yet the behaviour of the incidence curve is on the whole dissimilar. The number of sample trees taken is too small to decide if the difference is real or due to insufficient sampling.

OTHER LOCALITIES.—Mr. Unwin found the borer present in 1916 in plantations around Mohnit, Taikma and Nganzat, Kaing Reserve, especially in the 1905 plantation at Taikma and the 1893 plantation at Nganzat.

3. Incidence in Natural Forest.

On the high ground between the two plantations is a group of teak of similar size and development ; one of these (S. T. 17) was felled and analysed. Girth 41 inches ; age approximately 70 years ; fairly evenly grown with only one short (6 years) period of suppression. Total number of beeholes 8, their dates as under :—

TABLE 22.—*Annual Incidence in a 70 year-old Natural Teak, Kaing Reserve, Pyinmana, 1919.*

1848—1866	1867	1868	1869	1870	1871—79	1880	1881—1889	1890	1891—1905	1906	1907—1912	1913	1914—1917	1918
0	1	1	0	1	0	1	0	1	0	1	0	1	0	1

Arranged by decades the occurrence is fairly steady.

1869-1878.	1879-1888.	1889-1898.	1899-1908.	1909-1918.
3	1	1	1	2

3. PLANTATION NO. 5 OF 1895, YANAUNGMYIN RESERVE.

1. Description of the Sample Plots.

1916. An area for observing the ecology of the beehole borer was selected by Mr. Unwin in 1916 in this plantation; the incidence of attack was determined, beeholes plugged with bamboo pegs and marked with paint, and a plane-table survey made of the positions of the attacked trees. The following account of this area is taken from his report, and from information supplied by Mr. L. C. Davis, Divisional Forest Officer.

Area 1·67 acres; soil a good sandy loam; on a gentle south-east slope at about 500' above M. S. L.; growth of the crop poor mainly because of the lack of tending in the past.

Undergrowth. Fairly dense, the shrubs consisting chiefly of *Hemigraphis flava* and tree growth of *Homalium tomentosum*, *Stephegyne diversifolia* and other soft woods. *Cephalostachyum pergracile* fairly abundant.

Past History.—1899-1900 Cleaned; 1902-1903 stems seriously injured by fire cut back; 1906-1907 and 1915-1916 lightly thinned, *i.e.*, all growth interfering with dominant teak poles cut back and climbers removed; August 1918 thinned heavily. The light thinnings made previous to 1918 removed practically no teak; when inspected in April 1918 dead and stagnant teak poles formed the greater part of the stand and the canopy was composed mainly of small-crowned, semi-dominated trees.

Fires.—In 1902 about half the plantation was burned and in 1906 practically the whole area was traversed by fire. The location of the sample plot is rather moist and, with the exception of the 2 fires mentioned, has remained unburned in both fire-protected and non-fire-protected periods.

The plot (S. P. No. 31) was examined tree by tree on the 18th May 1916 and a total of 557 trees counted; of these 94 or 17 per cent. showed signs of attack. Mr. Unwin notes that nearly all were suppressed or dominated trees and that 6 well-grown trees felled in various parts of the plot were barked to see if occluded holes could be found; none were located.

A second area was selected and demarcated between the 15th and 29th June (S. P. No. 32).

Description.—Area 4·76 acres ; soil and location as in previous plot, but aspect west. Undergrowth as in previous plot. The plot contained 1,645 trees of which 400 or 24 per cent. showed signs of attack. Seventeen trees, that were not obviously attacked, were felled and barked ; 6 of these showed one or two holes.

1918. The area was inspected by the writer between the 3rd and 12th June 1918 ; detailed examination was confined to a small plot of 190 trees on 0·47 of an acre in the centre of the worst affected part of Mr. Unwin's larger observation area. The percentage of attack in 1918 was found to be 5, as against 39 per cent. for the same plot in 1916. The figure obtained at the first enumeration undoubtedly includes earlier non-occluded holes in addition to the 1916 holes. Of the 74 trees recorded as attacked in 1916, 4 were reattacked and 5 new trees were attacked. The plot was moderately thinned (72 trees removed and 118 left standing) and the whole of the undergrowth felled.

2. Results of Analyses.

Number of Trees Analysed—22. *Date of Analysis*—3rd-12th June 1918.

TABLE 23.—*Girth-Beehole Incidence in a 23 year-old Plantation, Yanaungmyin Reserve, Pyinmana, 1918.*

3 Inch Girth-Class.	Serial Number of Sample Tree.	Girth in Inches.	Class.	Number of Beeholes.	Arithmetic mean of Girth-Classes.	Arithmetic mean Beeholes per Girth-Class.
7—9	153 A	9	s	0	9·0	0·0
10—12	174 B	10	s	1	11·2	3·2
	134 c	10	s	1		
	176	12	s	8		
	136	12	s	5		
13—15	175 D	12	s	1	15·0	1·0
	149 A	15	s	1		
	158	16	s	6		
16—18	152 A	16	s	3	16·7	4·3
	174 D	18	s	4		
	130	19	s	9		
19—21	132 A	20	d	3	20·0	5·7
	154	21	s	5		
	172 A	22	d	11		
22—24	166	24	s	23	23·0	17·0
	129 A	25	d	17		
25—27	134 C	25	s	6	25·3	9·0
	152 E	26	d	4		
	162 B	29	s	19		
28—30	133 C	31	d	1	32·0	11·0
31—33	142	33	D	21		
34—36	200 A	34	D	25	34·0	25·0

The arithmetic mean girth of the sample trees is 20 inches; the arithmetic mean number of beeholes per tree is 6·8. The mean girth of a normal 23 year-old tree should be 30 inches, and the graph beehole value for this girth is 14·25, the graph beehole value for a 20-inch tree being 5·75. By selection (with reference to the analyses carried out in the following year, see later, pp. 83-85) the mean sample tree for this area has a girth of 26 inches; the girth-beehole curve gives 9·9 beeholes for this girth.

Annual Incidence.—The annual incidence is given in Table 24 and is shown in the Annual Incidence Chart as Group 3 (broken black line) of the Yanaungmyin series. Owing to the large number of suppressed trees only 14 out of the 22 could be reliably dated.

TABLE 24.—*Annual Incidence in a 23 year-old Plantation, Yanaungmyin Pyinmana, 1918.*

Serial Number of Sample Tree.	Girth in Inches.	1895 1896.	1900	1901	1902	1903	1904	1905	1	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	TOTAL.
174 D	18	..	..	..	..	..	..	..	1	0	0	0	0	0	0	2	0	0	1	0	4
200 A	34	..	..	..	..	..	..	..	0	0	0	2	0	2	6	3	3	1	3	2	25
152 E	26	..	..	..	..	..	..	..	..	..	..	2	0	0	1	1	0	0	0	0	4
154 .	21	..	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5
172 A	22	..	..	..	..	..	..	..	..	..	..	..	..	..	3	3	1	2	2	0	11
142 .	33	..	..	..	2	1	0	0	0	0	6	0	1	1	0	0	0	2	3	1	17
162 B	29	..	..	..	..	2	0	0	0	0	0	0	0	1	3	2	3	5	3	0	19
134 C	25	..	..	..	..	..	..	..	..	..	..	..	..	..	1	3	0	1	0	1	6
152 A	16	..	..	..	..	..	..	..	..	1	0	0	0	0	0	0	1	0	0	1	3
130 .	19	..	..	..	..	..	..	..	..	..	..	..	..	..	2	1	2	4	0	0	9
129 A	25	..	..	..	..	..	..	..	..	..	1	0	0	1	0	2	5	5	3	0	17
133 C	31	..	..	..	..	..	..	..	..	..	..	..	..	..	1	0	0	0	0	0	0
166 .	24	..	..	..	..	..	..	..	..	..	..	..	..	..	5	5	5	5	3	0	23
132 A	20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	0	1	0	0	3
TOTAL		..	1	0	2	3	0	1	1	1	9	4	1	5	23	24	20	29	18	5	147
Reduced Values			0·07	0·0	0·1	0·2	0·0	0·07	0·07	0·07	0·6	0·3	0·07	0·3	1·6	1·7	1·4	2·0	1·2	0·3	9·9

In August 1918 the plantation was thinned by the Burma Forest School and several trees were inadvertently cut out of the sample plot. It was later demarcated and surveyed, and the positions of the 85 remaining trees plotted.

1919. In April 1919 the area was again visited by the Forest Zoologist and trees felled in the thinning of August 1918 were used for analyses. In all 67 trees were analysed, but for 28 of these the stumps could not be located and the true girth breast-height and the true number of beeholes were not determinable; they are therefore considered separately.

Number of Trees Analysed, 39 [with stumps, felled August 1918].
Date of Analysis, 17th-26th April 1919.

TABLE. 25.—*Girth-Beehole Incidence in a 24 year-old Plantation, Yanaungmyin, Pynmana, 1918.*

3 Inch Girth-Class.	Serial Number of Sample Tree.	Girth in Inches.	Number of Beeholes.	Arithmetic mean of Girth-Class.	Arithmetic mean Beeholes per Girth-Class.	Adjusted means.
10—12	21	12	8	...	...	...
	23	12	2	...	...	...
	25	12	2	...	...	...
	28	12	3	...	...	...
	34	12.5	6	...	...	...
	35	12.5	8	...	...	...
13—15	37	12.5	1	12.2	4.3	4.3
	5	13	18	...	...	...
	7	15.5	1	...	...	...
	20	14	4	...	...	...
	22	14	10	14.1	8.2	8.2
	2	17	6	...	...	...
16—18	3	16	5	...	...	...
	12	17.5	14	...	...	...
	16	18.5	12	...	...	...
	26	17	13	...	...	...
	30	18	7	...	...	...
	31	18.5	9	...	...	...
19—21	36	18	2	...	...	...
	39	17	4	17.5	8.0	8.0
	8	21.5	5	...	...	...
	11	20	22	...	...	...
	14	20.5	0	...	...	...
	15	20	1	...	...	...
22—24	32	21	15	20.6	8.6	8.6
	6	24.5	20	...	...	...
	13	22	14	...	...	...
	18	22	21	...	...	...
	24	24	13	...	...	...
	27	24	9	23.3	15.4	...
25—27	9	27	7	...	...	16.3
	33	25	58	26.0	32.5	...
28—30	1	30.5	5	...	...	...
	4	29	10	...	...	...
	29	28	6	29.1	7.0	...
31—33	10	32	14	...	...	...
	19	31	20	32.1	18.3	18.3
	38	33.5	21	..	...	...

The arithmetic mean girth of 22 dateable sample trees of the above is 23.5 inches; the graph number of beeholes per 23.5 inch tree is 11.3. The arithmetic mean number of beeholes of the same 22 trees is 13.7; the mean girth on the girth-beehole curve bearing 13.7 beeholes is

27.0 inches. The mean girth of a 24 year-old tree according to Leete is 31.25 inches; the graph number of beeholes corresponding to this girth is 21. As the plantation is slow-grown, the arithmetic mean number of beeholes has been chosen as an index of attack for reduction.

Twenty-eight trees of which the stumps were missing were also analysed. For purpose of comparison with the whole tree data, the girths were uniformly measured at 4' 6" from the butt ends. If the distribution of beeholes throughout the tree were uniform the data in Table 26 below could be compared absolutely with those in Table 25, but since this is not so, an approximate comparison only is possible. The girth-beehole incidence in the trees minus stumps is given in the table below.

TABLE 26.—*Girth-Beehole Incidence in a 24 year-old Plantation, Yanaungmyin, Pyinmana, 1919. [Trees without stumps.]*

3 Inch Girth-Class.	Serial Number of Sample Tree.	Girth at 4' 6" from butt end.	Number of Beeholes.	Arithmetic mean of Girth-Class.	Arithmetic mean Beeholes per Girth-Class.
16—18	6	16	6	...	...
	1	18	1	...	...
	21	18	0	...	...
	19	18.5	13	17.6	5.0
19—21	4	21.5	7	...	...
	13	21.5	13	...	...
	18	21	10	...	...
	20	19	0	...	...
22—24	23	21	3	20.8	6.6
	2	24	10	...	...
	8	22	1	...	...
	9	23	9	...	...
25—27	10	22	2	...	...
	11	23	5	...	...
	17	24.5	4	...	...
	22	23	1	...	...
28—30	15	24.5	5	23.2	4.6
	3	25.5	7	...	...
	5	25	11	...	...
	7	26.5	4	...	...
31—33	12	27	5	...	...
	26	25	12	25.8	7.8
	16	28	2	...	...
	28	28.5	21	28.2	11.5
34—36	Nil.	...	...	...	...
	14	35	20	35.0	20.0

The arithmetic mean number of beeholes per sample tree is 7.0 and the arithmetic mean girth is 23.2.

A comparison of the arithmetic mean number of beeholes per girth-class in this table with those in Table 25 shows, that on the whole the trees without stumps show a lower number of beeholes girth for girth than trees with stumps. This is to be expected from a consideration of the vertical distribution of beeholes in the tree. As will be seen from Table 35, page 98, the basal 3 feet of the tree in this plot contains on an average 14.5 per cent. of the total number of beeholes in the bole.

Annual Incidence.—The ages of the beeholes in the 67 trees cut up were not determinable in all cases, particularly in very suppressed trees. Rejecting all doubtful datings, the annual frequency of the borer is shown by the data in the following 2 tables. Table 27 contains the results of 23 dateable trees with their stumps, and Table 28 the results of 21 trees without stumps.

TABLE 27.—Annual Incidence in a 24 year-old Plantation, Yanauungmyin, Pymnana, 1919.

Serial No. of Sample Tree.	1895-1896.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	TOTALS.
1	30	..	..	..	..	..	..	..	..	1	0	0	0	2	2	0	0	0	0	0	0	5
4	29	..	..	..	..	..	..	..	..	..	1	0	0	0	0	2	3	0	0	0	0	10
6	25	..	..	..	..	..	..	..	..	..	..	..	2	1	1	0	0	0	0	4	3	20
8	21	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	0	2	0	0	5
9	27	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	3	0	0	0	7
10	32	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	3	0	0	0	14
11	19†	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	2	2	6	0	0	22
13	22	..	..	..	..	..	..	..	..	..	..	..	..	..	0	1	1	3	0	0	0	14
15	20†	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	1	2	0	0	0	14
16	18†	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	0	0	0	0	1
19	31	..	..	..	..	..	..	..	..	..	..	..	..	..	1	3	1	3	4	1	0	12
31	17†	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	0	4	4	1	20
18	22	..	..	..	..	..	..	..	..	..	..	..	..	..	1	4	0	0	5	5	0	14
24	24	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	1	0	4	3	4	21
29	28	..	..	..	..	..	..	..	..	..	..	..	..	..	1	0	0	0	4	2	0	13
30	18	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	1	2	1	0	0	7
31	18†	..	..	..	..	..	..	..	..	..	..	..	..	..	0	2	1	1	1	0	0	9
32	21	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	3	0	2	2	2	15
33	25	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	5	0	9	1	58
36	18	..	..	..	..	..	..	..	..	..	..	..	..	..	1	18	0	4	11	0	0	2
38	33†	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	0	1	3	0	21
17	25†	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	1	1	4	0	1	4
39	17	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	1	1	4
TOTALS	..	1	1	0	1	3	1	0	0	5	5	6	7	9	49	52	20	30	55	38	21	304
Reduced Values	..	0.05	0.05	0.0	0.05	0.1	0.05	0.0	0.0	0.3	0.2	0.3	0.3	0.4	2.1	2.4	0.9	1.3	2.5	1.8	0.9	13.7

This incidence is plotted in the Chart (solid red line) as Group 1 of the Yanaungmyin series; the total of 13.7 beeholes being that for a mean tree of 27 inches.

In the next table, Table 28 are given the figures for the annual frequency in 21 trees of which the stumps were missing.

TABLE 28.—*Annual Incidence in a 24 year-old Plantation, Yanaungmyin, Pymana, 1919.*
[Trees without stumps.]

Serial No. of Tree.	Girth at 4' 6" from Butt-end.	1896-1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	TOTALS
1	23.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
3	24.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10
3	25.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	7
4	21.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
5	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11
7	26.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
8	22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
6	23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
10	22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
11	23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
12	27	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
13	21.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
14	35	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
15	24.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
16	28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
17	26.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
19	18.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
22	23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
23	21	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
26	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
TOTALS	..	..	1	1	0	0	2	4	3	0	10	7	5	3	2	19	14	12	21	28	8	9	149
Reduced Values	..	..	0.09	0.09	0.0	0.0	0.2	0.4	0.3	0.0	0.9	0.7	0.5	0.3	0.2	1.8	1.3	1.1	2.0	2.5	0.8	0.8	13.7

The data in the preceding table are plotted on the Annual Incidence Chart as Group 2 of the Yanaungmyin series in solid black. The reduction value for the mean tree is the same as that for Group 1, *i.e.*, 13.7 beeholes.

If the three incidence curves are mutually compared, it is evident that there is a marked general resemblance, particularly in the period 1910-1918, and, as the data for one of the curves were collected 12 months before those for the other two, and no adjustments have been made for the loss of stumpage in Group 2, the working error is very small.

The height distribution of the beeholes in this sample plot is discussed on page 99. (*Vide* Table 35 and Diagram 3).

Other Localities.

Mr. Butterwick found *ceramicus* larvæ in the 1895 plantation on the 1st August 1915 and notes that empty larval galleries were numerous.

Mr. Unwin records the presence of the borer in 1916 in most of the Yanaungmyin plantations, more especially in No. 5, of 1895, No. 6 of 1896 and No. 3 of 1893, but less abundant than in the last two. In natural forest no instances of borer attack were discovered.

Natural Forest.—On the 11th June, 1918 a teak tree, one of a group in unclassified forest just outside the Reserve, was felled by the Forest Zoologist and analysed. Its girth was 4' 8"; the number of 9 inch billets cut up was 82; the only signs of borer attack found were in billet No. 1, failed larval work of 1896, and billet No. 69, a larval gallery of 1909. It may be noted that this tree stood close to the fire-line which is burnt annually.

4. Sample Plot in North Toungoo.

1. PLANTATION 1873, PYONCHAUNG RESERVE.

1. Description of the Sample Plot.

The plot was selected by Mr. W. C. Rooke, Extra Assistant Conservator of Forests in the south-west corner of the Pyonchaung Reserve; as an observation area in April, 1916 (area 1.70 acres). The crop is fairly dense and chiefly remarkable for its excessive height growth due to the absence of thinnings early in the history of the plantation. The average girth of the trees was about 3' 3½" in 1916, with some of 6' 3" on the margins towards the open.

Undergrowth.—Rather scanty, consisting of shrubs up to about 15 feet and occasional small trees up to about 30 feet; creepers relatively few; bamboos absent; grass and *Urena lobata* occasional.

Past History.—There is no record of silvicultural operations previous to November 1911, when the plantation with others was thinned, and opened up where miscellaneous tree growth was encroaching. The plantation is said to have been successfully fire-protected up to 1914, from which year light fires have passed through it annually.

2. Enumeration and Analyses.

In April and May 1916, Mr. Rooke surveyed the area and plugged all emergence holes as soon as they were detected; a total of 211 emergences from the plot of 188 trees was recorded, 34 per cent. of the trees being attacked. Between 21st and 30th May 1918, the Forest Zoologist inspected the area, and enumerated the attack. Fresh beeholes were found in 71 trees, *i.e.*, 38 per cent.; the distribution of the attack was quite irregular. Of the 63 trees noted to be attacked in 1916 only 29 were reattacked in 1918; 42 trees, not recorded as attacked in 1916, showed evidence of borer emergence in 1918. The number of beeholes pegged in 1918 was 116, against 211 in 1916. The number of trees not attacked during the period 1915-1918 is 82 or 44 per cent. of the plot. These trees lie mostly in the northern quarter of the plot, where the undergrowth is densest; several occur in the centre of the plot where the canopy is somewhat open, and several stand near one edge where the teak is very branchy or strongly shaded by other tree growth. There is thus a slight suggestion that trees are less attacked where undergrowth or adjoining jungle gives lateral shade, and sample trees were chosen for analysis to test this condition. The results however defy interpretation.

Number of Trees Analysed—6 : *Date of Analysis*—21st-30th May 1918.

TABLE 29.—*Girth-Beehole Incidence, Pyonchaung, North Toungoo, 1918.*

Serial Number of Sample Tree.	Girth in Inches.	Age.	Class.	Number of Beeholes.
1	44	50	d	16
2	40	49	D	53
9	34	45	D	95
62	34	45	D	33
170	33	45	d	26

Tree No. 1 was felled in the edge of a patch of teak in an 1868 plantation, isolated by encroachment of miscellaneous jungle, and was surrounded on three sides by high tree growth. No. 2 was a dominant, in a well-stocked plantation of 1869 with a fairly thick undergrowth of *wanwe* forming a canopy at 20 feet. No. 62 grew under conditions similar to No. 1. No. 9 and No. 170 were surrounded by a fair amount of low undershrubs.

In the girth-beehole graphs the indices for the 49-50 year-old trees and the 45 year-old trees are shown separately. It may be noted that if combined they would show a mean value practically the same as that for Okkyi, Shwegu.

The annual distribution of dateable beeholes is given in the following table.

TABLE 30.—*Annual Incidence in 45-50 year-old Trees, Pynchaung, North Toungoo, 1919.*

Serial Number of Trees.	Age.	1868-188	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Total.	
1	50	..	1	0	0	0	0	2	1	0	1	1	2	1	0	0	1	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	16	
2	50	1	0	1	1	0	0	0	1	1	0	0	0	2	3	0	0	1	0	0	2	2	3	0	0	7	11	4	1	7	4	3	2	53
9	45	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	4	3	1	11	7	6	28	30	3	95
62	45	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	0	0	0	0	0	0	1	0	1	1	2	1	6	0	3	10	5	1	33
TOTALS	..	1	1	1	0	1	1	2	1	0	2	2	2	1	1	2	2	0	1	0	0	2	3	4	2	5	14	15	21	8	16	42	38	6	197	
Reduced Values.	..	0.2	0.2	0.0	0.2	0.2	0.5	0.2	0.5	0.2	0.0	0.5	0.5	0.5	0.2	0.5	0.2	0.5	0.0	0.2	0.0	0.0	0.5	0.7	1.0	0.5	1.2	3.5	3.7	5.2	2.0	4.0	10.5	9.5	1.5	49.0

For the trees in the 1873 plantation, *viz.*, Nos. 9, 62, and 170, the arithmetic mean girth is 34 inches, and the arithmetic mean number of beeholes is 51. (Leete's girth for a mean tree of 45 year-old is 47 inches, which from graph readings should have a total of 72 beeholes). For the sample trees of the 1868 and 1869 plantations the mean girth is 2 inches and the mean number of beeholes is 34.5. The normal girth of a typical 49 year-old tree is nearly 48 inches; this tree should have total of 45 beeholes. For the purposes of the Annual Incidence Graph the arithmetic mean number of beeholes of the dateable trees (*i.e.*, excluding 170) has been taken, and this value, 49.2 beeholes has been used in the reduction of the actuals.

It will be observed that the attack, in the case of all four dateable trees, commenced relatively late, *i.e.*, after 23 to 33 years in the 1873 plantations, and after 17 years in the 1868 and 1869 plantations, and that a particularly heavy attack occurs in 1915 and 1916 on one tree, S. T. 9, which is not represented in the other trees. The number of sample trees taken is too small to permit generalisations, but it is evident from the difference between the behaviour of the insect in this area and its behaviour in the younger plantations, that further analyses in this locality will be very instructive.

The vertical distribution of beeholes in these trees is shown in Table 35, p. 98.

5. Sample Plot in South Toungoo.

1. PLANTATION NO. 1 OF 1905, BONDAUNG RESERVE.

1. Description of the Sample Plot.

An area 0.47 acres containing 243 trees selected as an observation area in March 1916, situated on a south-west slope about 300 feet above m. s. l.; soil a sandy loam somewhat eroded. Quality of the growth rather below the average.

Undergrowth sparse, mainly a few coppice shoots of *Terminalia chebula*; for practical purposes the undergrowth is negligible.

Past History. Cleaned 1910, 1911, 1913, and 1915; thinned December 1917 with neighbouring plantations. Fire-protected up to and including 1915; burned April 1st, 1916, in 1917 and in 1918.

2. Enumerations and Analyses.

1916. The plot was surveyed and all trees examined by the divisional staff up to a height of 20 feet in March 1916; of the 243 trees 48 or

20 per cent. were recorded as attacked, and in all 58 beeholes of 1916 emergence or of previous years, were plugged and marked with paint. Six trees were felled and split (2 dominant, 3 dominated and 1 suppressed) and 3 of them were found to contain beeholes. The distribution of the attack by quality class of tree was found to be as follows :—

Dominant, 14 out of 110	=	13 per cent.	} = 48 out of 243 or 20 per cent.
Dominated, 21 „ 84	=	25 per cent.	
Suppressed, 13 „ 49	=	26 per cent.	

The plot was again examined between the 8th and 11th June 1916, and the number of fresh larval attacks was recorded. 122 trees (50 per cent.) were found to show signs of attack, the relative incidence in the quality classes being as under :—

Dominant, 59 out of 110	=	54 per cent.	} = 122 out of 243 or 50 per cent.
Dominated, 46 „ 84	=	55 per cent.	
Suppressed, 17 „ 45	=	35 per cent.	

In an area within the plantation adjacent to the sample plot, enumeration were made in May 1916 and the following data on the distribution of the attack were obtained :—

Dominant, 40 out of 181	=	22 per cent.	} = 102 out of 395 or 26 per cent.
Dominated, 26 „ 102	=	25 per cent.	
Suppressed, 36 „ 112	=	32 per cent.	

It will be noticed that in suppressed trees, while the percentage of fresh larval attack is lowest, the percentage of visible beeholes is highest. The latter condition is due to the fact that the slower occlusion of beeholes in suppressed trees allows a relatively larger number of holes to remain visible, than in dominant and vigorous trees where the rate of healing is quicker,

Life History Observations.—In March 1916, emergence had already occurred in 4 per cent of the trees in the sample plot; empty pupal skins were observed on the 3rd and 4th May; fresh larval work was encountered between the 8th and 11th June. Larvæ were also found by Mr. P. Burnside, Extra Assistant Conservator of Forests, on the 29th and 30th May and 2nd June 1917.

1918. The area was again enumerated (F. Z.) in May 1918, and a close scrutiny of the whole bole up to the crown branches was made on each tree. Thirteen trees only, or 5.4 per cent. showed emergences of 1918 at heights of 1-20 feet above ground; the attacked trees were distributed irregularly over the plot, and of the total number only 2 [S. T. 98 and 173] had been recorded as showing attack in 1916. The results of the analyses of trees felled at the time of enumeration

together with 4 trees felled in December 1917 is given in Table 31 below.

Number of trees Analysed=15 [including 4 felled in the 1917 thinning.] *Date of Analysis*=12th-17th May, 1918.

TABLE 31.—*Girth-Beehole Incidence in a 13 year-old Plantation, Bondaung, South Toungoo, 1918.*

3 Inch Girth-Class.	Serial Number of Sample Trees.	Girth in Inches.	Number of Beeholes.	Arithmetic mean of Girth-Class.	Arithmetic mean Beeholes per Girth-Class.
10—12	49	10	2	...	...
	47	12	0	...	...
	25	12	4	...	...
	58	10	3	10.66	2.16
	27	10	0	...	...
13—15	88	10	4	...	...
	52	15	1	...	...
	43	13	1	14.0	1.0
16—18	2	18	3	...	...
	173	17	3	17.5	3.0
	66	19	5	...	...
19—21	98	21	5	19.7	4.7
	5	19	4	...	...
22—24	3	24	15	...	...
	4	24	15	24.0	15.0

The arithmetic mean girth of the sample trees is 15.6 inches and the arithmetic mean number of beeholes per tree is 4.27. From the girth-beehole graph based on the above class means, the beehole value for a typical 13 year-old tree of 18.3 inches girth is 3.8. Compared with other plots this is a rather high index of attack; from records in the plantation journals and observations made by the divisional officer, the neighbourhood of the Thabyewa is apparently badly infested by the borer.

The annual distribution of the 64 beeholes in the dateable trees is as follows :—

TABLE 32.—*Annual Incidence in a 13 year-old Plantation, Bondaung, South Toungoo, 1918.*

	1905-1908.	1909.	1910.	1911	1912.	1913.	1914.	1915.	1916.	1917.	TOTAL.
Combined Attack 15 Trees.	0	2	1	4	6	9	5	13	13	12	64
Reduced values	0.00	0.12	0.06	0.25	0.38	0.57	0.32	0.83	0.83	0.76	4.0

6. Sample Plot in Tharrawaddy Division.

1. PLANTATION NO. 87 OF 1896, COMP. 9, KONBILIN RESERVE.

1. *Description of the Sample Plot.*

Growth.—The plantation (area 4·4 acres) is one of several close together formed in 1890-1898 after the flowering of *bamboo*. All are much reduced in area by the encroachment of the surrounding forest, and are also very patchy within their boundaries. Eight sample trees were analysed in Plantation No. 87 near the western edge of the Reserve on flat ground forming the flood-plain of a small stream. The soil is of fairly good quality, a stiffish loam inclined to be somewhat water-logged but, according to Mr. H. R. Blandford, Divisional Forest Officer, not first-class soil for teak; similar localities would now be planted, with *Pyinma*, *L. Flos-Reginae* or some other species more suited to the locality. In the forest near the plantation, outside the reserve, there is practically no teak.

Undergrowth.—On the whole dense and high, extending up to 2-3rds of the bole length, representing encroachment and infiltration early in the life of the plantation. The principal woody species are *Millettia Brandisiana*, *Dolichandrone arcuata*, *Ficus glomerata*, *Dysoxylum binectariferum*, *Stephegyne diversifolia* with the bamboos *Cephalostachyum pergracile* and *Bambusa polymorpha*. In many places these form part of the canopy and occasionally occupy parts of the plantation area to the complete exclusion of teak.

Past History.—Mr. Blandford informs me that fire protection was probably started in 1876 and certainly from 1888. The plantation or the surrounding forest was burnt accidentally in 1897. Protection was abandoned from 1916 south of the plantation, but an accidental fire occurred in 1918 just north of the plantation. The sample trees were selected near the edge of the Reserve, outside which the forest is burnt annually. In 1910-1911 the sample plot and the neighbouring plantations were lightly thinned.

2. *Results of Analyses.*

Number of Trees Analysed—8. *Date of Analysis.*—17th-22nd June, 1918.

TABLE 33.—*Girth-Beehole Incidence in a 22 year-old Plantation, Konbilin, Tharrawaddy, 1918.*

Serial No. of Sample Tree.	Class.	Girth in inches.	Height in feet.	Bole in feet.	No. of Beeholes.
2	s	15	57	39	1
7	s	15	40	35	2
4	s	19	64	40	0
5	D	22	0	43	0
6	D	30	75	45	4
1	D	30	70	42	3
3	D	35	84	62	7
8	D	40	68	41	8
Arithmetic mean	...	25.75	...	...	3.12

On plotting these data to obtain the girth-beehole curve, the graph value for a girth of 25.75 inches is found to be 2.25 beeholes, and for a girth of 29.0" (being Leete's value for a 22 year-old tree) is found to be 3.25 beeholes. This is an exceptionally low index of attack in comparison with indices of other sample plots, and may be due to the fact that the plantation has lost much of its purity and approaches the condition of a rich patch of natural teak forest. There is however very little natural teak nearby.

The sample trees were chosen with a view to determining if the affect of undergrowth is appreciable on single trees, and the following descriptions are therefore recorded, although the results are negatived by the unexpectedly low general incidence.

Tree No. 2. Suppressed, under 2 co-dominants; surrounding undergrowth lopped.

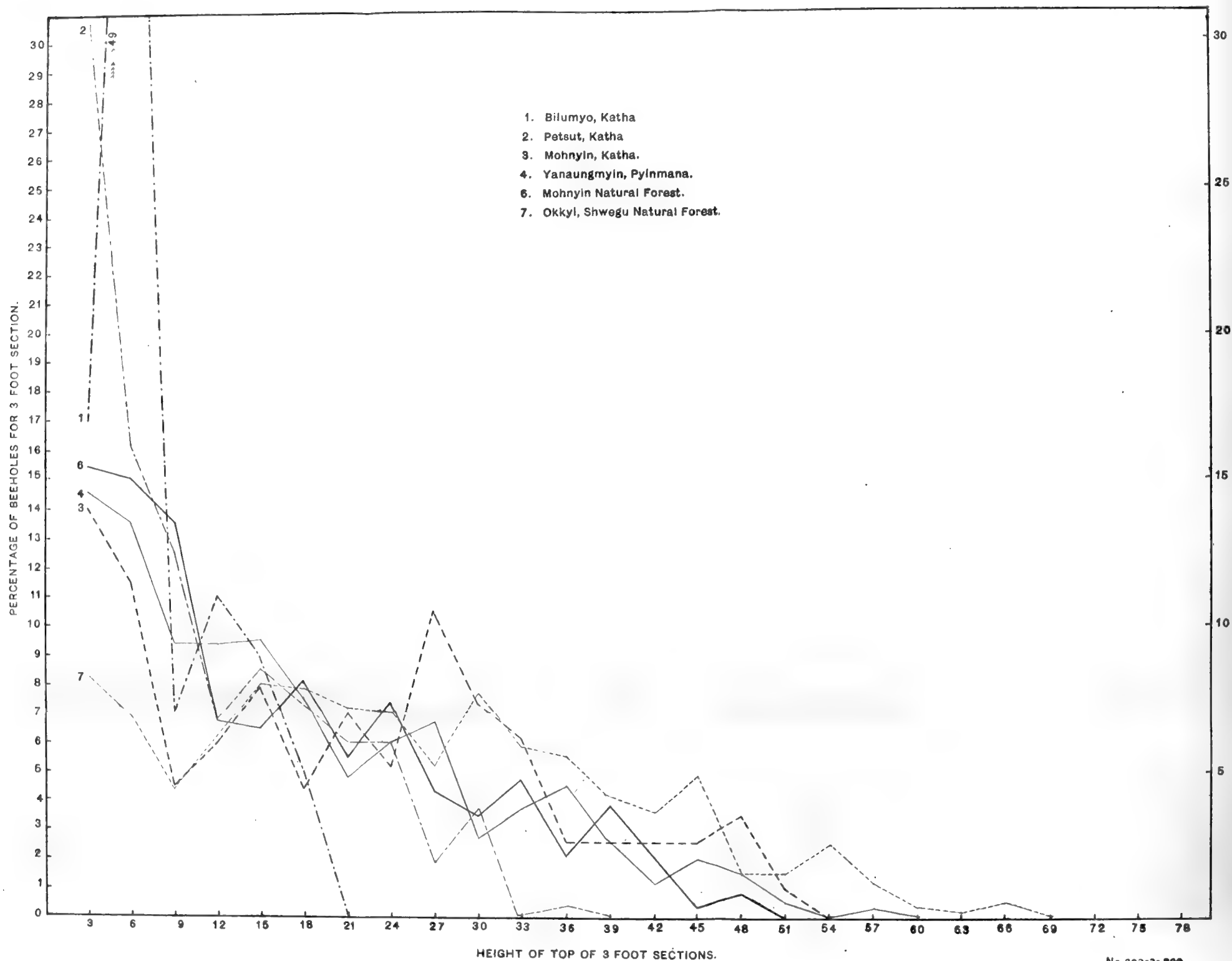
Tree No. 7. Suppressed by teak, but in an alluvial flat with much bamboo and soft woods intermixed.

Tree Nos. 4 & 5. Dominated by bamboos.

Tree No. 6. Dominant on a slight slope, overtopping several suppressed teak; *tinwa* clumps on all sides up to about 30.'

Tree No. 1. Dominant, well surrounded by suppressed trees, bamboos and undergrowth.

(vide also Table 35.)



HOLES.

(*vide also Table 35.*)

DIAGRAM 3.

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Tree No. 3. Dominant ; thick underwood of bamboos, *kyathavungwa* and *tinwa*, and shrubs ; some old lopped bamboo clumps.

Tree No. 8. Dominant over No. 7 and other teak ; *tinwa* abundant, but lopped.

The annual incidence in these trees is given in the following table :—

TABLE 34.—*Annual Incidence in a 22 year-old Plantation, Konbilin, Tharrawaddy.*

Serial No.	Girth	1896-1904.	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	TOTAL.
2	15	..	..	0	..	..	1	0	0	0	0	0	0	0	0	1
7	15	..	2	0	0	0	0	0	0	0	0	0	0	0	0	2
6	30	..	1	..	..	..	..	1	0	2	0	0	0	0	0	4
1	30	..	..	..	..	..	..	..	..	..	..	..	..	2	1	3
3	35	..	..	..	..	..	..	..	2	0	0	0	4	1	0	7
8	40	..	..	..	..	..	1	0	0	1	0	0	0	3	3	8
TOTALS .		..	3	0	0	0	2	1	2	3	0	0	4	6	4	25
Reduced Values .		..	0.39	0.0	0.0	0.0	0.26	0.13	0.26	0.39	0.0	0.0	0.52	0.78	0.52	3.25

In the Annual Incidence graph the values for this group of sample trees are plotted as for a mean tree of 29.0 inches girth with 3.25 beeholes.

The Vertical Distribution of Beeholes.

[Diagram 3.]

There is a considerable diversity of opinions as to the abundance of beeholes in different parts of the teak tree. In plantations the divisional officer gets the impression that beeholes occur low down near ground-level ; in girdlings the lessee considers they appear most commonly in top logs and the top ends of logs. The following figures will show the actual distribution of beeholes in the trees analysed in sample plots.

The trees are divided into lengths of 3 feet from ground-level upwards ; the number of beeholes in the same 3 feet length of all the sample trees is determined, and this total is reduced to a percentage of the whole number of beeholes.

A reference to Table 35 and Diagram 3 will show the percentage of beeholes occurring in any 3-foot length of an average tree.

TABLE 35.—*Vertical Distribution of Beeholes.*

	Locality. 1	Locality. 2	Locality. 3	Locality. 4	Locality. 5	Locality. 6	Locality. 7
Total Number of Beeholes.	22	219	114	378	226	234	518
Total number of Trees.	40	19	25	39	5	15	19
<hr/>							
Height in feet above ground level.	Percentage of Beeholes in each 3-foot length.						
66—69	..	..	..	..	0.0	..	0.0
63—66	..	..	..	..	0.4	..	0.5
60—63	..	..	..	..	0.8	..	0.1
57—60	..	..	..	0.0	0.8	..	0.3
54—57	..	..	..	0.3	0.4	..	1.2
51—54	..	..	0.0	0.0	0.8	..	2.4
48—51	..	..	0.9	0.5	1.7	0.0	1.5
45—48	..	..	3.5	1.5	2.6	0.8	1.5
42—45	..	..	2.6	2.1	3.1	0.4	4.8
39—42	..	..	2.6	1.06	5.7	2.1	3.6
36—39	..	0.0	2.6	2.6	8.4	3.8	4.1
33—36	..	0.4	2.6	4.5	3.3	2.1	5.5
30—33	..	0.0	6.1	3.7	12.8	4.7	5.8
27—30	..	3.6	7.9	2.6	3.2	3.4	7.7
24—27	..	1.8	10.5	6.6	4.0	4.3	5.1
21—24	..	6.0	5.2	6.08	7.0	7.3	6.8
18—21	0.0	6.0	7.0	4.8	6.6	5.5	7.2
15—18	5.0	7.3	4.4	7.4	8.8	8.1	7.7
12—15	9.0	8.6	7.9	9.5	8.0	6.4	7.9
9—12	11.0	6.8	6.1	9.3	4.0	6.8	6.3
6—9	7.0	12.3	4.4	9.3	3.1	13.6	4.3
3—6	49.0	16.4	11.4	3.5	5.7	15.0	6.8
0—3	17.0	30.6	14.0	14.5	0.0	15.4	8.2

LOCALITY No. 1. Regeneration, 1911, Bilumyo, Katha, 1919.
 " " 2. Plantation No. 2, 1897, Petsut, Katha, 1919.
 " " 3. Plantation, 1898, Mohnyin, Katha, 1919.
 " " 4. Plantation No. 5, 1895, Yanaungmyin, Pyinmana, 1919.
 " " 5. Plantations 1868 and 1873, Pyonchaung, North Toungoo, 1918.
 " " 6. Natural Forest, Mohnyin, Katha, 1919.
 " " 7. Natural Forest, Okkyi, Shwegu, 1919.

In the young 8 year-old plantation (Locality 1) no beeholes occur above 18 feet, and half of them occur between 3 and 6 feet. This fact is of some importance from the point of view of control; in the first thinning trees showing beeholes should be removed, and since half of the visible beeholes are likely to occur opposite the marking-officer's eyes their detection is within practical limits.

In the 22 year-old plantation (Locality 2) a concentration of the half the total number of beeholes is still within the first 6 feet, but above 10 feet the beeholes suddenly thin out and steadily decrease in number to the crown.

In the 21 year-old plantation (Locality 3) although about the same age, the distribution different; only 25 per cent. of the beeholes occur in the lowest 6 feet of the bole, and above this height the distribution is fairly even with a slight increase between 25-30 feet.

In the 24 year-old plantation (Locality 4) the basal 6 feet likewise contains $\frac{1}{4}$ of the total number of beeholes; thence the quantity steadily falls with the increase in height.

The Pyonchaung data (Locality 5) are quite different from the rest, and, as they are based on 5 trees only, are not typical of local conditions; the curve is not shown in Diagram 3.

The two plots in unevenaged natural forest (Localities 6 and 7) give somewhat dissimilar results. The plot at Mohnyin yields a graph that resembles that for Quarry Siding plantation (Graph No. 3) and also that for the Yanaungmyin plantation (Graph No. 4). The Okkyi plot, on the other hand, is peculiar in its more or less even distribution for the 40 feet of the bole.

The conclusions drawn from a consideration of these data are as follows:—

- (1) In a young plantation 10-15 years, at least half the total number of beeholes occurs in the basal 6 feet of the tree.
- (2) As the plantation grows older the intensity of attack on the upper sections of the bole relatively increases, and the proportion of beeholes in the basal 6 feet decreases. In a 25 year-old plantation only 25 per cent. of the total number of beeholes may occur in the lower 6 feet.
- (3) At later ages the distribution of beeholes throughout the bole becomes more even, with an average of 6 per cent. per 3 foot length.
- (4) At all ages, up to 50 years, there is a marked decrease in the percentage of beeholes in the upper and younger portions of the bole.

What happens in trees over 50 years old is, in the absence of analyses, conjectural; but it is possible that after height growth has ceased the intensity of attack increases in the upper portions of the bole, and produces, by the time the tree is felled, a fairly even distribution of beeholes.

As regards the effect of fires and of undergrowth on the distribution of beeholes, nothing can be deduced from the data in their present forme

BEEHOLES IN MATURE TREES.

The foregoing records are from trees mainly below the age of 50 years. Through the kindness of Messrs the Bombay Burma Trading Corporation Ltd., the writer was able to spend a day in their Rangoon Mill, in June 1919, examining the occurrence of beeholes in mature teak logs.

The number of beeholes exposed on the sawn faces of the slabs, planks and squares of 5 logs was determined; each beehole was traced out with a split bamboo probe so that, when it appeared in section on both sides of one or more planks, it should not be counted more than once. The following table summarises the results.

TABLE 36.—*Number of Beeholes in logs of Mature Trees.*

No. of Beeholes.	Log No.	1	2	3	4	5
	Large	9	45	3	27	108
	Small	21	103	35	60	313
	Total	30	148	38	87	421

Log No. 1.—Chindwin Forest, Kalewa District; 16'-0"×7'-2". A log with rotten heart, and lenticular patches of rot derived from branch stubs. Cut into 4 slabs, 4 planks and 1 square.

Log No. 2.—Chindwin Forest, Kindat District; 18'-0"×7'-5". Rotten heart and numerous rotten patches connected with branches. Cut into 4 slabs, 5 planks and 1 square.

Log No. 3.—Chindwin Forest, Kindat District; 25'-0"×6'-11". A fairly sound log. Cut into 4 slabs, 4 planks and 1 heart.

Log No. 4.—Pyinmana Forest; 20'-0"×7'-0". Cylindrical heart rot. Cut into 4 slabs, 4 planks and 1 square.

Log No. 5.—Shweli Forest; 20'-0"×6'-6". Fairly sound. Cut into 4 slabs, 4 planks and 1 square.

As the central square bears no constant relationship to the annual zone of growth and only a part of the beeholes present in the log is exposed, it is impossible to deduce from these observations if beeholes do or do not "become more numerous towards the centre of the log." It is reasonable to estimate the total number of beeholes in the tree of which log 5 formed a part at *well over a thousand*.

Some Conclusions.

The data recorded in the preceeding pages have been presented in detail, as their interpretation is by no means obvious. The writer has attempted to draw certain conclusions in order to form a working hypothesis for future research, but he is quite prepared to admit the

possibility of other interpretations. Various theories are current with regard to the natural history of the borer and its control and it may be profitable to discuss the validity of some of them in the light of the foregoing data.

1. THE LIABILITY OF TREES TO ATTACK.

Since the borer habitually breeds in living trees it has been generally assumed (by analogy with the habits of other borers) that it attacks most readily weak, suppressed, moribund and girdled trees. From the method of feeding and the construction of the beehole it is now evident that *vigorous trees are beeholed in preference to weak or decadent trees* (*vide* pp. 55 *et. seq.*) From the stem-analyses in even-aged crops it is evident that *the average number of beeholes per tree is directly proportional to the girth*, other factors being equal. [*vide* Sample Plot Records and Diagram 1] The question now arises: "Is this relationship due to the selective action of the female moth during oviposition, or to an independent factor such as the area of bark surface exposed per girth-unit, or the composition of the crop and the laws of probability governing the moth+tree combination?"

(1) The first explanation cannot be admitted unless we venture into the unknown and assume a nicely graded series of chemotropic responses stimulated by variations in the growth vigour of the tree. (2) The composition of the crop is not the dominant factor since the highest and lowest girth-classes include the smallest numbers of trees, hence both should show lower incidences of attacks than the middle girth-classes, proportional to the probability of concurrence between female moths and trees. (3) If we explain the higher frequency of beeholes in higher-girth trees as due to the greater area of bark surface (or volume), we assume that there is competition between the borers for feeding-space. The following example will show the absence of overcrowding and consequent lack of competition. In a 21 years old plantation the mean number of moths emerging per tree of mean girth 28" is 0.5 per annum [Mohnyin, 1898]. There are, in a normal crop, 170 trees per acre at 21 years (Leete,) hence $170 \times 0.5 = 85$ moths per acre; of these assume half are females, *i.e.* 42.5. Without making reductions for mortality before oviposition, we have available 42 moths to attack 170 trees; as each individual lives only a few days and the moth emergence period extends over 8 to 10 weeks, oviposition is not influenced by competition. On the contrary *individual trees frequently escape attack for several years*. For example in a sample plot in a Pyonchaung plantation (1873) the percentage of trees attacked in 1916 = 38 per cent.; in 1918 = 34 per cent.; and of the whole stand 44 per cent. remained unattacked

during the period 1916-18. Again 22 trees in a plot [Yanaungmyin, 1895] remained unattacked for 6 years out of 10, and in another plot [Mohnyin, 1898] 21 trees remained unattacked 7 years out of 10. The greater available bark-space on higher girth trees is therefore not the decisive factor. (4) It is suggested that the frequent occurrence of high numbers of beeholes in the higher girthed trees of an evenaged crop is the result of a relatively higher percentage of survivals to the pupal stage in such trees. The liability to attack is not greater,—in any case the number of eggs laid on a particular tree by a particular moth is a matter of pure chance, as the Sample Plot Records show—but *the liability of larvae to successful development is proportional to the richer food-supply*. Vigorous trees provide the most certain food-supply and produce the healthiest borers and the largest beeholes. An examination of the analysis data shows that there is a tendency for beeholes of maximum size to occur in rapidly grown crops, and that in slow-grown crops beeholes are smaller and accompanied by a higher proportion of failed larval galleries.

2. THE ANNUAL INCIDENCE AND RATE OF INCREASE OF THE BORER.

The annual incidence curves given in Diagram 2 show that (in pure evenaged stands) the borer *usually appears early in the life of the plantation and may appear as early as the 2nd year after foundation*, vide also Plate IV. The current annual incidence, thereafter, fluctuates considerably but the mean annual incidence increases steadily although relatively slowly (vide also p. 56). The most important fact arising from the data is the recognition of *a very low rate of increase and frequent natural reductions in the mean annual incidence*. It suggests that a possible method of control in plantations lies in the forced growth of teak, i.e. in *the production of a high girth-increment in individual trees*, so that the wood-increment outstrips the borer-increment. The writer has compared the annual incidence curves with all the known measureable factors, viz. (1) total annual rainfall, (2) mean annual temperature, (3) occurrence of thinnings, and (4) of fires, (5) incidence of woodpeckers, and with none of these is there constant agreement of effect.

(1) and (2) *Effect of Rainfall and Temperature*. The data yield negative results, possibly because the meteorological stations are at considerable distances from the sample plots.

(3) *Effect of Thinnings*.—After a thinning the incidence curves behave irregularly, but there are indications that thinnings can be carried out so as to reduce the incidence of the borer.

(4) *Effect of Fires*.—The use of fire as a means of controlling the beehole borer has frequently been advocated. Mr. W. N. Grieve was the first

to bring forward facts in support of the idea that forest fires are destructive to the teak borer, *e.g.* in the Indawgyi forests (*vide* p. 11). Since then others have recorded cases in which beeholed timber is abundant in forests annually fired. In view of these contradictions it is necessary to theorise.

If timber full of beeholes is extracted nowadays from forests that are never burned, and also from forests traversed by fierce fires the anomaly can be explained by inferring that fire-conditions and beehole production are not stable. In certain types of teak forest, fires are accompanied by profuse reproduction of teak, but in others, although teak seedlings readily appear, they are equally readily destroyed; in fire-protected forests or in moist mixed forests becoming evergreen, teak regeneration is scarce or non-existent. Abundant second growth of teak, particularly in pure or rich patches, means excellent facilities for the local increase of the borer and consequent overflow attack on neighbouring trees of greater age. Both high and low incidences of borer attack may thus be associated with fires, and low incidences with absence of fires. High beehole incidence in forests now evergreen and poor in teak postulates rather more extensive but not improbable changes in the flora.

As regards the direct effect on the insect, it may be presumed that a ground-fire running through a teak forest will destroy *ceramicus* moths alive on that day and scorch eggs laid on the lower parts of the trunk. Subsequent fires are likely to be less fierce. The emergence period of the moth extends over at least 3 months locally [*March—June*] and the average length of life of a moth is about a week. Assuming that 180 moths emerge per acre (*i.e.*, double the incidence recorded on p. 101) the number alive on any day will be $8 \left(\frac{180}{90} \right) = 16$; hence it is doubtful if more 32 moths per acre, or 18 per cent will be destroyed directly by fire in one season. The incubation period is apparently prolonged and the possible destruction of eggs by a later fire is high; with inflammable undergrowth the zone of destruction is extended much higher up the bole. A smaller proportion of beeholes should be found in the lower parts of the bole than in the upper parts in fire-traversed areas. Such data as have been collected by the writer cannot be used for comparison because of the absence of reliable past history with reference to fires, and until such is available the effect of fires cannot be evaluated.

Effect of Undergrowth.—Data are contradictory: *e.g.* in the Okkyi plot absence of undergrowth is associated with a low or falling incidence; in Bondaung a very sparse undergrowth is connected with a very high incidence; in Mohnyin the incidence is not affected by the introduction of an artificial undergrowth; in Pyonchaung low incidence is connected with a dense stand and high incidence with an open wood and sparse

undergrowth; in Petsut the girth factor dominates the undergrowth factor (*vide* p. 70). The conclusions arrived at in 1918 as to the effect of undergrowth (Forest Zoologist's Report, 1918, p. 3, para 4) are not of general application.

Control Measures.

Although the investigation in its present state can by no means be considered to supply results of immediate practical value, the publication of the available information provides concrete ideas on the extent of the damage due to this pest, and indicates the direction in which research is required for the enucleation of control measures.

As far as natural forest is concerned nothing can be done to reduce the damage in girdlings of the next 10 or 20 years. The beeholes are already in the tree, and the additional attacks received during that period will affect the sale price in only a very small proportion of the logs.

In plantations and regeneration areas of pure and more or less even-aged teak the following measures are suggested :—

1. Thinnings should commence early and recur at short intervals and should be carried out so as to produce a high girth-increment in individual trees, as there are indications that the girth-increment can be made to outstrip the borer—increment. The statistical data will afford a means of adjusting the two factors to the development of the maximum yield of sound timber in the final crop.

2. In early thinnings or cleanings, trees showing beeholes should be cut out unless their retention is silviculturally essential, but in the middle period of the rotation the presence of visible beeholes should not influence the selection or rejection of trees.

3. In thinnings the suppressed and dominated trees should be cut out and not left standing, as it is evident they do not act as trap-trees, but on the contrary are sources of infection to the more vigorous trees.

4. The most favourable time to fell is between August and December. If trees are felled early in the year the borers in the mature larval and pupal stages will complete their development successfully.

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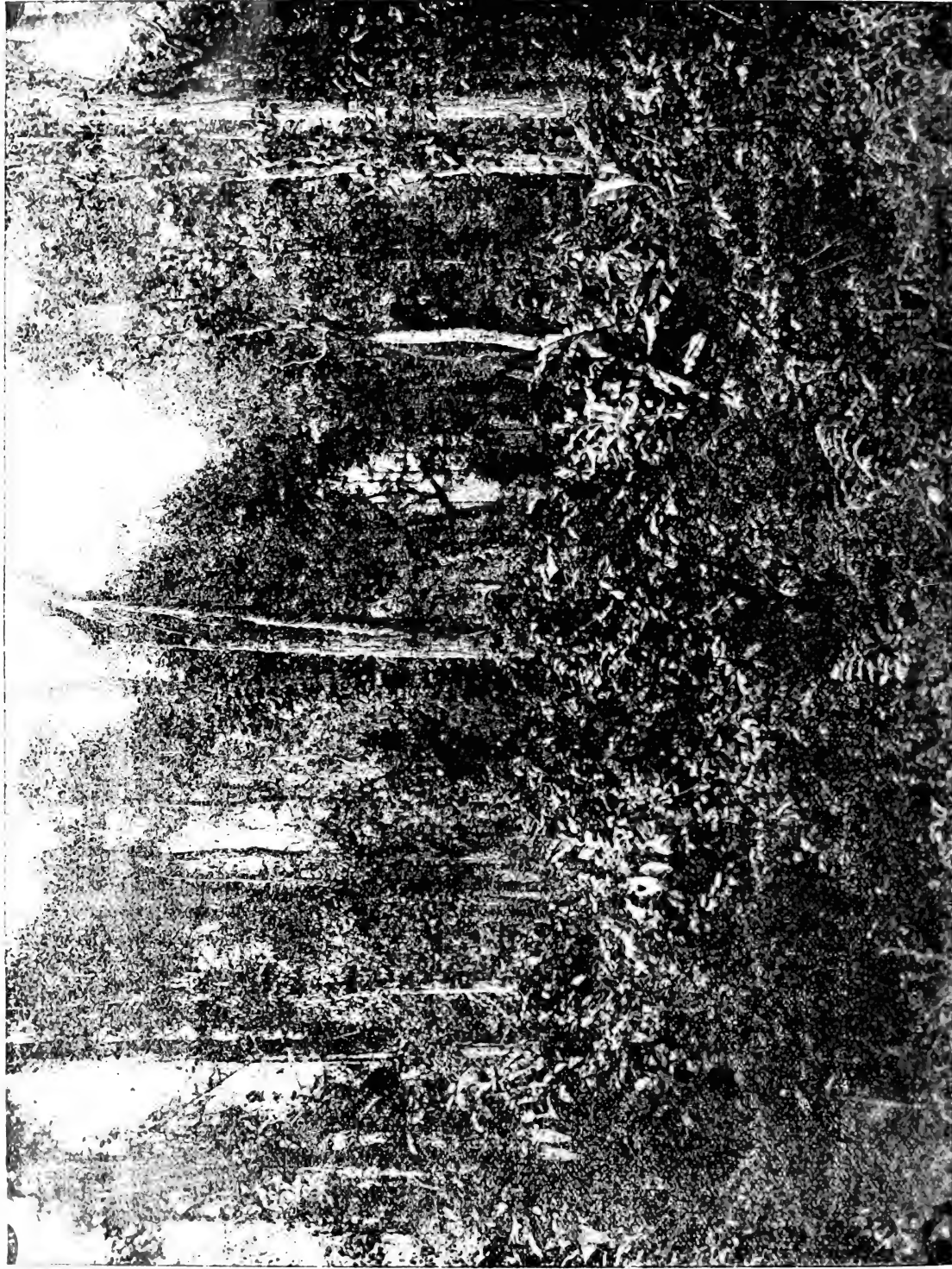
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[Part IV

PART I.

Artificial Regeneration of Sal in the Low-level Forests of the Duars.

BY

A. K. GLASSON.

I. Brief history of the Forests.

1. Some thirty years ago the sal forests in the Duars contained besides the sal and a few of its fire-resisting associates, nothing but grass. Successful protection from fire resulted in a gradual change, evergreen undergrowth came in and killed out the grass, trees of species susceptible to fire established themselves, and climbers became abundant. Natural regeneration was adversely affected by these changes and, after a time, measures to assist it were prescribed. The following extracts from Working Plans shew the state of affairs in 1905-06 :—

Buxa Division Working Plan 1905.

“The younger age classes are on the whole fairly well represented. Natural reproduction (of sal) is satisfactory where not unduly handicapped by the dense herbaceous undergrowth and creepers that spring up under all openings made in the canopy. The sal in these forests has, however, the power of coming up and maintaining existence under a canopy which is complete enough to prevent or kill out the dense herbaceous undergrowth mentioned above ; but under such a canopy it does not advance beyond the stage of weedy

saplings a few feet high, which are easily destroyed by small creepers.”

This plan prescribed the felling of :—

- (I) All sal trees over 2' in diameter not required for seed.
- (II) Unsound and unpromising sal trees under 2' diameter when interfering with the development of more promising neighbours.
- (III) Trees of species other than sal when interfering with sal or with trees of other species more valuable than themselves and adds :—

“ No sal tree should be cut in improvement fellings unless it suppresses or otherwise seriously interferes with more promising stems of the same species and is obviously so defective that it cannot grow into a good tree over 2' diameter. The thinning of dense groups of sal poles should be of a light description, and should merely allow adequate space for the development of the more promising trees in the group. No group should be thinned unless the trees composing them have clean boles. As regards the removal of species other than sal the main object is to progressively uncover the natural reproduction of sal and other valuable species without unduly encouraging herbaceous undergrowth.”

The Revised Working Plan for Jalpaiguri Division 1906 in addition to felling rules similar to the above, prescribed that, after an improvement felling, each coupe so dealt with should be cleaned and weeded every year for five years to establish both the sal regeneration already on the ground and that which appears in the year after felling.

In both these Working Plans it was forecasted that the measures laid down would result in the successful establishment of ample seedlings. There is no mention in either plan of artificial regeneration and at that time 1905-06 it was certainly not considered necessary to experiment with it.

2. From this time onwards the advisability of continuing fire protection was often discussed and in 1910, when it was known that the results of the cleanings and weedings had fallen short of expectations, experiments in burning and in artificial regeneration were started. The five-year cleanings were finally condemned as a failure in 1914 and the condition of the forests at that time was fully described by Messrs. Grieve and Shebbeare in an article on “Sal Regeneration in the Duars Forests” (*Indian Forester*, April 1914).

The following quotation may be made from the latter.

“In the wet type, established saplings or seedlings do not exist although, as before, yearling seedlings are of fairly common occurrence, especially on cleared lines and cart tracks. There is, unfortunately, every indication that the wet type is encroaching on the dry, owing, presumably, to successful fire protection. In fact it would appear that, when the present crop of sal has been exhausted, there will be no more to take its place. The first thing that strikes a forester returning after several years is the remarkable increase in evergreen undergrowth and the almost complete absence of sal between the seedling and pole stages under healthy seed-bearers.”

* * * * *

“It was hoped and expected that by eliminating fires and grass there would be no difficulty in obtaining and maintaining perfect sal forest; unfortunately an entirely new and unforeseen condition arose in the shape of evergreen undergrowth producing a hitherto non-existent type of forest. The phenomenal increase in the growth of climbers resulting from the exclusion of fires was also not anticipated.”

Natural regeneration in the fire-protected areas was practically non-existent. Conditions to-day are substantially the same as described in the above article; ground fires have been put through some of the sal forest with beneficial effect to the existing crop but without inducing regeneration and in many places we are exploiting the trees which came in after fire protection was established.

II. Experiments in artificial regeneration.

3. Prior to 1910 some experiments had been made in artificial regeneration of sal with the object, generally, of introducing sal where it was not formerly found, in grass lands and abandoned village sites. The records of such sowings are meagre and the only successful plantation now traceable is the one in North Muraghat made in 1896, 1897 and 1899. This sowing was made on good, fairly well drained land the *modus operandi* being as follows. Grass land was cultivated and sal seeds put in close together in lines 6' apart among the first crop. It was intended that the land between the lines should be cultivated with crops in the 2nd year, but the villagers declined to do this. The sowing was therefore only cleaned and cleanings appear to have ceased in 1899. For the

1896 sowing which was the most successful the rate of growth is given as below :—

	Average.	Best.
Age 1 year	1' 2"	1' 9"
2 „	2' 6"	4' 9"
3 „	6' 0"	10' 0"
4 „	11' 11"	16' 6"

There is no record of the number of plants which survived, but it is stated that the plants near the roads were best. The records cease at 1902 and the next observations were made in 1915 when the average girth and height of best trees were 2' 5" and 70' and the best tree was 2' 11" in girth.

Other sowings on the same lines were made but were not successful and sowings were discontinued from 1903. This is probably to be attributed to a lack of interest or rather a lack of motive as it seemed unnecessary to spend money from the scanty funds available on regenerating a species which was believed capable of reproducing itself naturally. It should be noted that this sowing suffered considerably from the inroads of Mallata (*Macaranga* sp.). As late as 1918 sal seedlings could be found which had only reached a height of some 10' owing to suppression by Mallata. Similar seedlings freed in 1915 had made good progress.

4. The experiments of 1911 and 1912 aimed at reproducing sal under top cover, generally that of Mallata. Germination was good but the seedlings did not develop and opening out the top cover resulted in heavy undergrowth which proved fatal to the sal.

5. The only sowing made in 1913 was in abandoned village lands, without top cover. The grass was burnt off and the area ploughed and then worked up into ridges and furrows. Sal seed was sown on the ridges and germinated well. The area was small and cleanings were done as often as necessary. This plantation was a success, there were no blanks and, on the better drained portion, the plants grew rapidly. The cost was however very high—not less than Rs. 60 per acre up to the time the best plants were well established.

6. The success of this sowing led to the abandoning of sowings under shade, but the exact procedure followed in 1913 was very costly, so in

1914 mounds 1' high and 2' square were made at intervals of 10' instead of ridges. All these sowings were in grass—generally old village land. Germination was generally good and seedlings developed well in the first year. Grass was kept in check as far as possible, but the quantity of labour required was very large, it was found difficult to keep the plants clear and where cleaning got in arrears development was arrested. The actual wiping-out of the seedlings in the 2nd or 3rd year is to be attributed to pigs and rats, but a considerable number appear to have died from drought where the mounds were not properly made. In the year 1915 mound-sowings were repeated and a further cheapening was effected by reducing the mounds to very small dimensions resulting in so-called "sod-sowings". These sods were made 6' × 6' apart. The results of mound sowings were as before and sods proved equally good where the land was not low. The subsequent cleaning of the sods was even more laborious than in the case of mounds.

7. To follow the next step that was taken it must be realised that the first years results of mound and sod sowings were considered successful and it was thought that, given land similar to that in which these sowings were made, *i.e.* abandoned cultivation sites covered with grass, we could grow sal. As the available land of this nature was very limited it was proposed to give out for cultivation areas likely to be suitable for sal but at the time under inferior species and to cultivate them till clean. Such areas were in fact marked out early in 1915 in Buxa Division but were not taken up by the villagers and later, in 1915, an area in a cleared fuel coupe in Jalpaiguri Division was cultivated by villagers. When it was seen how clean the land became after one crop of paddy, cotton and sessamum, it seemed unnecessary to cultivate for 3 to 5 years as had been intended and in 1916 sal was put in in the 2nd years cultivation in Muraghat (Jalpaiguri Division) and in 1st year's cultivation at Nimati and Poro (Buxa Division). The correctness of this procedure was confirmed by the fact that mound sowings and sod sowings in grass had proved unmanageable on any scale on account of the labour required for cleaning and had been seriously threatened if not destroyed by pigs and rats. The result of the first sowings in cultivation were so good that no other methods have been attempted from 1917 onwards.

III. Present method.

8. The procedure now adopted is as follows. The area is clear felled of everything and made over to the villagers by the end of February. They clear and burn and cultivate a mixed crop of paddy, cotton, sessamum with a few chillies, gourds, etc. In May or June sal is sown amongst this

crop either in lines or "thalis"* generally lines 6 feet apart. The sal is "tullied" in July or August, after removal of the paddy crop, and again in September or October. In the second year a further crop is taken, generally the same as in the first year or cotton only, and, if there are blanks or patches of ground unsuitable for sal, these are planted up with seedlings of other species from nurseries. The sal seedlings are not seriously hindered by this second crop which ensures clean ground up to the end of the second rains. After removal of the crop the seedlings of sal are cleaned and tullied and should be 3' to 4' in height. Up to this time no payment is made, all the work being done free by villagers in return for the crops they get from this area and from their wet cultivation. Sal sown in June of one year is made over, clean, at the end of the rains (October) of the following year. After this cleanings are paid for. It appears that one cleaning and tulling costing about Rs. 5 per acre will be necessary at the beginning of the third rains and possibly two subsequent rounds of jungle cutting costing about Rs. 2 per acre, after this the plantation should be self supporting.

9. The cost of regenerating sal by the method above described varies considerably according to the condition of the land on which the plantation is made. For good sal land covered with tree growth the cost is low as, when the land is taken over from the forest villagers after removal of the second crop, the plants should be about 4' in height and standing in clean ground; at the end of the following rains the plants should be 8' in height ($2\frac{1}{2}$ years old) and a year later they should be 12' to 14 high and forming a complete canopy. Up to this point the cost should be less than Rs. 10 per acre. In addition the villagers are allowed rent-free land for wet cultivation, homesteads etc. It is estimated that one household can regenerate one acre per year so that on an 80-year rotation and allowing 5 acres of rent-free land per household $\frac{5}{80}$ ths or less than 7 per cent. of the area would be under villages and this is precisely the least valuable land for the production of forest crops.

10. Plantations made by this method have been successful in all cases where there has been no great damage by pigs; but several promising sowings have been entirely destroyed by pigs and the only remedy appears to be fencing. Fences of bamboo, of wood, or of reeds, put up by the villagers have not proved successful. Even if the fence is strong enough to keep out pig, larger animals break it down and pigs use the gaps. Wire fencing has been tried round two plantations in Kurseong Division with success and further experiments on a larger scale are now being made. Where fencing is necessary the cost per acre of establishing

*Note.—A "thali" is a planting-hole of loosened earth and from this the verb to "tully" i.e., pull up weeds and loosen the soil round a plant has been coined.

the new crop will be considerably higher than the figures given above. Exact costs are not available but the estimate for wove wire fencing works out at less than Rs. 20 per acre ; so it is anticipated that the total cost will not exceed Rs. 30 per acre which is well within the economic limit.

IV. Conclusion.

11. This method of regeneration is only applicable where forest villagers can be settled. It may prove possible to work part of the dry sal forests in a similar way with hired labour and this is being tried now. The same method is being used for the regeneration of other species, in areas not suitable for sal with the difference that in the case of faster growing species such as Toon, Gomari and Simal, only one year's cultivation is possible.

12. Much remains to be done before we can hope to regenerate the full annualcoupe under the Regular Method, but in Buxa Division alone some 160 acres of sal forest was regenerated by this taungya method in 1919 and the area should increase rapidly as the villagers become trained to the work.

PART II.**The Taungya System in Northern Bengal.**

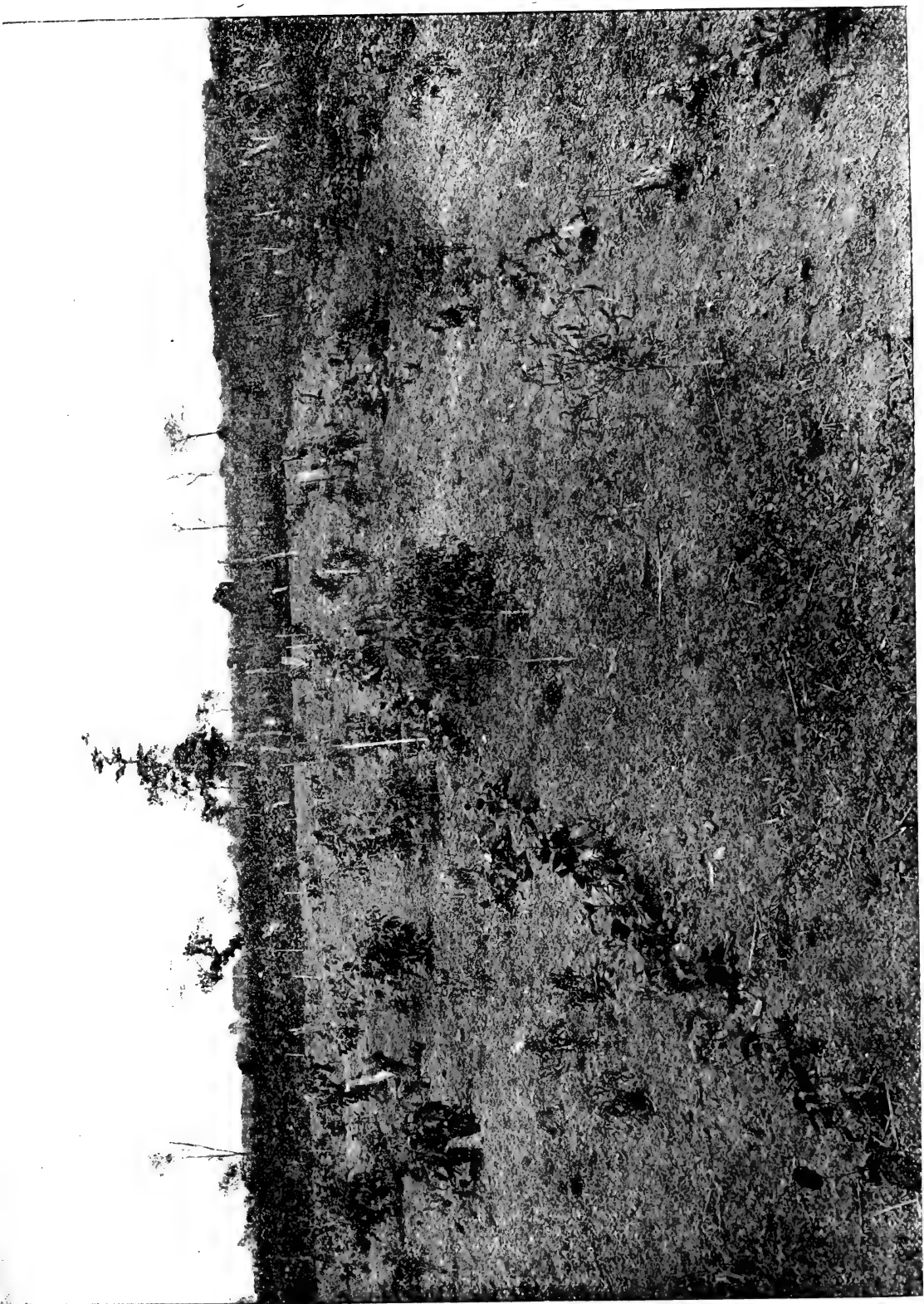
BY

E. O. SHEBBEARE.

Although the Taungya System in Bengal, even regarded as a broad principle, is scarcely out of the experimental stage yet, it has been suggested that whatever information exists concerning it ought to be made known and I have therefore been asked to write this account. Rather than appear to be "sitting on" information which might be of interest to foresters in other provinces, I am including, for what they are worth, some recent ideas and suggestions still under experiment along with the details of methods more or less established by experience. This experience has been gained partly by the Forest and partly by the Cinchona Department which has been systematically planting up forest after the removal of the Cinchona crop on the Mongpoo plantation for the last twelve or thirteen years, at the rate of about 250 acres annually. It is to Mr. Russell of the latter department that we owe most of what we know concerning the work in the middle and foot hills as well as up-to-date nursery practice throughout.

2. The reason for introducing the system was the unsatisfactory state of natural regeneration of all the more valuable species both in the plains and the hills, in the former probably due to conditions induced by successful fire protection. In the case of sal, not only are natural seedlings scarce and established saplings absent but even the pole stage is often wanting in forests in which the mature crop is mainly sal. Something had to be done, and the result of experiments, many of them on a considerable scale and extending over several years, led to the rejection successively of intensive weeding, regulated burning and various methods of supplementing natural regeneration, in favour of clear-felling and restocking. Further experiments pointed to field-crops as the surest means of establishing the plants, a conclusion arrived at, curiously enough, by the Cinchona and Forest Departments quite independently at about the same time.

3. The history of the idea of employing field-crops to establish forest crops (long known under its Burmese name of "taungya") goes back some way even in Northern Bengal, for an attempt to establish sal



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Photo-Mech. Dept. Thomason College, Root Kca.

Photo by T.R. Chitrakar,

A Sal taungya in its second year; Nimati sowing of 1918, Buxa Division. Area 16 acres. Plants 17 months old—average height 18 inches to 2 feet. Second crop of cotton just removed, cotton still standing on the right. 1917 sowing in the background.

in grass-land in Jalpaiguri by this means between 1896 and 1899 remains, in part, a perfect success and the failure of the other part appears to be due mainly to neglect and absence of incentive, for, at that time, the aim was to introduce sal where none existed and no anxiety was felt for natural reproduction in existing forests. Taungya plantations mostly of Tun (*Cedrela* spp.) and Lampati (*Duabanga sonneratioides*), were started in 1908 and the best of them are a great success. It was, however, Mr. Troup, after his visit to these forests in 1914, who first proposed taungya on a large scale as the only apparent means of regenerating sal and this, together with the success of the Cinchona Department's forest plantations, led to the extensive adoption of the system in Northern Bengal. It may be of interest to note that teak taungyas were made in Chittagong as long ago as 1870 though the idea was abandoned and not re-started until 1912.

4. The general method consists in clear-felling a piece of forest in the cold weather and, after the timber and firewood have been removed, allowing forest villagers to burn the debris and sow the area with their own crops among which the forest plants are grown. These, whether sown or planted, are generally put out six feet apart in the plains and somewhat closer in the hills either on "thalis" (planting-holes one foot square and deep, filled up again with the loosened soil after stones and roots have been removed,) or in continuous lines in the case of sal. When possible each area is kept under crops for two or even three years, the forest plants being, as a rule, put in with the first crop in the plains and the second in the hills; the Cinchona Department however put the plants in after the last field-crop has been reaped. In many cases a shortage of cultivators precludes more than one year's cultivation and the faster-growing species sometimes completely close up so as to prevent a second crop being taken. The presence of forest plants does not interfere with the cultivation of the field-crops as, in any case, no plough can be used on account of the roots. The amount of attention required depends upon the species to some extent but more than anything on the quality of the cultivation round the plants. Sal may require weeding and forking two or three times in the first year, twice in the second and once or twice in the third, while a fast growing species often requires nothing more than frequent cutting out of superfluous stems.

5. The field-crops most commonly grown in the plains are either a mixture of rains paddy, maize and cotton or maize alone followed by millet; the former being preferable from our point of view. Rape or buckwheat is sometimes sown at the end of the rains and several minor crops such as sesamum, chillies and various pulses are sown at the same

time as the main crop. In the hills maize and millet followed by potatoes is the commonest crop but a great variety including barley and occasionally oats and a sort of wheat is grown. Recent experiments carried out by the Cinchona Department have proved the forest soil at 6-7000 feet and even higher to be suitable for growing *Digitalis* and *Belladonna* and a chemical firm have just applied for permission to grow medicinal herbs in our hill taungyas. This may make cultivation at high elevations more popular. At one place in the plains which will be referred to later an experiment in growing the field-crops departmentally is being tried; here the Agricultural Department has assisted us with advice and supplied us with the best varieties of seed.

6. The trees grown include a large number of species, the rule at present being to try any useful tree which appears to do well in the locality. As there seems to be no insurmountable difficulty in growing any desired species, the question of what to grow on a given site resolves itself into one of relative rates of growth combined with the probable market values which the silviculturist and economist can eventually answer. *Sal* and *Cryptomeria japonica* are grown pure and *Tun* is grown in mixture on account of the twig-borer but, for the rest, the question of pure crops or mixtures remains undecided. The general practice in the Forest Department is to grow pure crops or to mix the species in fairly large patches whereas the Cinchona Department favours mixtures by single trees and sometimes mix quite a number of species together. The species most commonly grown at the different elevations are given in the following paragraphs.

7. In the plains *sal* is the most valuable species and, incidentally, the one most difficult to grow as it requires good cultivation round it to make up for its comparatively slow growth. The question has sometimes been raised as to whether it might not be more profitable to replace *sal* by some faster-growing valuable species, especially as *sal* being purely a heavy construction timber, is more likely to be superseded by steel than lighter, more elastic or handsomer woods. As a counter to this it is pointed out that it is not likely to be superseded for sleepers and that there is probably no part of India where it grows faster or is of better quality. Whatever may be the truth in this matter, the present policy is to sow *sal* wherever it seems likely to do well. In places in the plains unsuitable for *sal* the species most frequently grown at present are *Gomari* (*Gmelina arborea*), *Kainjal* (*Bischofia javanica*), *Tun* (*Cedrela Toona* and *microcarpa*), *Chikrassi* (*Chickrassia tabularis*), and *Simal* (*Bombax malabaricum*) but several others which, for various reasons have been grown only on a comparatively small scale, appear likely to be at least as profitable; among these are *Champ* (*Michelia Champaca*),

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Photo-Mech. Dept. Thomson College, Roorkee.

A Sal taungya in its third year; Borodabri; sowing of 1917, Buxa Division. Area 28 acres. Plants

Photo by T. P. Chitrakar.

30 months old—average height 8 feet. The land here is better for Sal than that at Nimati and

Latter (*Artocarpus Chaplasha*), Lali (*Amoora Wallichii*), Karam (*Adina cordifolia*) and Sissu (*Dalbergia Sissoo*). Of late years very little has been done with teak in this part of Bengal though there are some fairly large plantations dating back to 1867 some of the trees in which are over 7ft. in girth, in spite of the fact that the plantations have suffered severely from want of thinnings. Recent plantations of teak in Chittagong have also been very successful and it will be tried on a larger scale in Northern Bengal this year.

8. The foot-hill country up to about 3,000 feet is the area in which the fastest growth occurs and taungya here is easy. The species most commonly grown are Lampati (*Duabanga sonneratioides*), Panisaj (*Terminalia myriocarpa*), Mandani (*Acrocarpus fraxinifolius*), Tun (*Cedrela* spp.), Chikrassi (*Chickrassia tabularis*) and Kimbu (*Morus laevigata*). At this elevation Lampati and Mandani often come up naturally after clearing and cultivation as will also Kadam (*Anthocephalus Cadamba*); this however, in spite of its very fast growth, is not considered valuable enough to be retained unless all else fails.

9. From 3,000 to 5,000 feet the Forest Department has less experience but the gap is filled by the Cinchona Department which has planted large areas at this elevation. The typical species here are Utis (*Alnus nepalensis*), Saur (*Betula cylindrostachys*) and Chilauni (*Schima Wallichii*) throughout with Kainjal and the foot-hill species in the lower parts and Pipli (*Bucklandia populnea*) in the higher. The Chilauni is grown by the Cinchona Department chiefly for firewood.

10. Above 5,000 feet Utis, Saur and Pipli continue and the "upper-hills" species begin. Of these the most commonly planted are high-level Champ (*Michelia excelsa*), some oaks (*Q. lamellosa*, *glauca* and *lineata*), *Cryptomeria japonica* and walnut. Most species are planted in the early rains but Champ and walnut are planted in the cold weather; the latter which is very fast growing in its early stages, is put out in depressions, and especially on old charcoal-kiln sites. A chestnut (*Castanopsis Hystrix*) produces what, after Champ, is probably the best timber found at this elevation, but it has not been planted as much as it should have been lately owing to the difficulty of getting sound seed. As far as can be seen at present, the most profitable crop from 5,000 to 7,000 feet is pure *Cryptomeria* which has been extensively planted and grows very fast after the first three years. It is remarkable that, while natural regeneration of indigenous species is so inadequate, pure plantations of this exotic 24 years old produce dense patches of seedlings wherever light is let in and, to judge by appearances, there would be no difficulty in working such areas on the Group System. Another exotic (*Eucalyptus*

Globulus) I believe holds the high-level record for rapid growth, in the early stages at any rate, some plants having reached 10 to 14 feet in height in 20 months at 6,000 feet elevation. Twenty-three species of *Eucalyptus* are being tried at various elevations this year. Above 7,000 feet taungya becomes difficult owing to the damage done by hail to the field-crops.

11. Nursery and planting practice as carried out by the Forest Department has changed very considerably in the last few years, following the example of the Cinchona Department which owes the success of its plantations largely to the excellence of its work in the early stages. Until recently Forest nurseries were roughly made of the ordinary local soil and not shaded and the plants were left in them until they were two feet or more in height and then put out, generally too late in the season, in recently cleared forest where they had to contend with vigorous coppice shoots and climbers from the start. Now seed is germinated in shaded beds of leaf-mould or a rich mixture of this with the local soil, and the plants are pricked out three inches apart in similar beds as soon as they are big enough to handle—say three inches long including the root. The result of this is to produce plants with relatively large and very fibrous and compact root-systems the whole of which can be picked up and planted with a handful of mould. This is done when they are only a few inches high and a few months old in large, well-loosened planting holes which do not bind the roots under which conditions plants will establish themselves with a minimum of tending, the most expensive item in plantation work. The above is the procedure in the case of an average species; very vigorous plants like Gomari can be grown with far less attention, especially on a light soil, but, in the main, experience has shown that it is more economical to spend labour in forcing plants along in their early stages than to spend it in keeping them alive under unfavourable conditions later. In the case of upper hill species it is best to make the nursery at the lowest elevation at which the tree is found, or even lower, so as to get rapid growth.

12. Plants larger than those just described are put out in the case of species the seed of which ripens late in the season (say anything after April) and will not stand storing until the following year. Such plants have to be kept in the nursery through the cold weather and put out at the beginning of the following rains when, being large, they have either to be root-and-shoot pruned or stripped of their leaves. Some species such as Tun and Chikrassi can be transplanted successfully in the cold weather. At high elevations the oaks are sometimes kept in the nursery for three or four years before being pruned and put out; this is partly owing to their slow growth and partly to the absence of seed in some

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A taungya at 6000 feet. Unplanted land in the foreground ; planted area with huts and shaded nursery-beds in the background.



Photo-Mech. Dept. Thomason College, Roorkee.

Photo by T. B. Chitrakar.

Closer view of the planted area showing *Utis* (*Alnus nepalensis*) about 8 months after planting.

years. Several species, including sal, teak, Simal, Latter, the oaks and probably Gomari, are better sown direct than transplanted from a nursery. Transplanting sal by means of root-and-shoot pruning, although it has been done, is not really necessary in Bengal where rain during the seed-time can be depended on.

13. Labour and good cultivation, as will be gathered from the foregoing paragraphs, is the key to the whole situation and in this respect Northern Bengal conditions are far from ideal. The plains, though fertile, are among the most malarious districts in India and, although cultivators are willing enough to face fever in return for the rich yield of irrigated paddy-land, they need some greater inducement than dry cultivation among the stumps and roots of a freshly-felled coupe, even though the land is given rent free. From the foot of the hills up to three or four thousand feet conditions in this respect are the most favourable; here hill-men can live close to their crops and in a healthy climate while, not being accustomed like the people of the plains to broad flats of irrigated paddy, they are content with the good crops of maize and millet which can be raised with little effort from the virgin soil of clear-felled coupes. Above this elevation the yield of the field-crops begins to fall off but this is balanced, within reach of bazaars, by better prices for produce while, in less accessible places, the Lepchas, a tribe of taungya-cutters of retiring habits, are often ready to settle. Above 7,000 feet the poor crops (practically nothing but potatoes) and the damage done by hail render cultivation unpopular.

14. The terms between the Forest Department and the villagers vary considerably. The ideal arrangement, from the point of view of the department, is to give the land of a cleared coupe rent-free in return for a crop of forest plants maintained free of cost up to the end of their second rains, but such terms are only possible in the most popular situations generally near the foot of the hills. Elsewhere either some part of the work has to be paid for or, as has been done in most parts of the Jalpaiguri and Buxa Divisions, some low land is set aside in each felling-series for irrigated paddy and the members of each household in the village attached to the felling series are allowed to cultivate an acreage of this in proportion to the area of dry "taungya" cultivation undertaken by them. As irrigated cultivation is permanent while dry cultivation is shifting the reduction in the area available for growing timber is negligible; moreover land suitable for wet crops will not grow any valuable species. It is always necessary to provide paid work for villagers in slack times and when they need money but there is plenty of line-clearing climber-cutting etc. to keep them employed. Loans are made when necessary to reliable villagers and recovered by work done; in some

cases debts to money-lenders incurred before the families entered the forest have been paid off and recovered in this way. Other privileges such as free fuel and grazing for a pair of plough cattle and two cows for each household act as an inducement to settlers.

15. The number of households required to the acre varies. Sal sowings need the most intensive cultivation and field-crops for two years are essential so that at least one household to every acre of annual coupe is necessary. Faster growing species can be raised with less thorough cultivation round them and, in the case of the most vigorous, where only one season's field crops are necessary or possible, three acres to the house may be managed.

16. An experiment in growing the field-crops departmentally is being made this year in a place where it is difficult to get sufficiently thorough cultivation done by settlers. The idea here is to employ a regular labour force to cultivate crops grown from good seed under the advice of the Agricultural Department. It is hoped to make a profit on these crops in spite of the high cost of the labour but, should it result in a loss, it is believed that this will not exceed the cost per acre spent on establishing the forest plants in similar situations at present. The arrangements with the labour for this experiment are more or less on tea-garden lines; a "sirdar" has been guaranteed regular employment for a certain number of coolies for a year at a fixed daily rate with a commission for himself. He has also been promised a bonus at the end of the year for each cooly who works continuously. Wages are paid to the coolies direct for ordinary work which is given out at a fixed daily task; some classes of work, however, are given to the sirdar on contract.

17. Fencing is a most expensive item but, though it is seldom necessary in the hills, it is essential in the majority of places in the plains where, without it, deer and bison will exterminate most species other than sal which is attacked by pig. These latter have reduced a fully stocked sal sowing to a blank in the course of a few days, generally at the end of February and beginning of March, preferring plants in their second year though first year seedlings are far from immune and even third year saplings fourteen feet high have been uprooted and destroyed. Several types of fencing have been or are being tried, the general conclusion at present being that nothing but wire fencing in one form or another is likely to be of any use. Barricades of wood or bamboo have been tried but are of very little use against anything but village cattle; they cost less than 6 per cent. of the cost of wire in the first instance and are a little more expensive than wire in upkeep. A form of fencing that has proved effective consists of one of the various makes of woven wire to a height of three-and-a-half to four feet with a strand of barbed wire one foot

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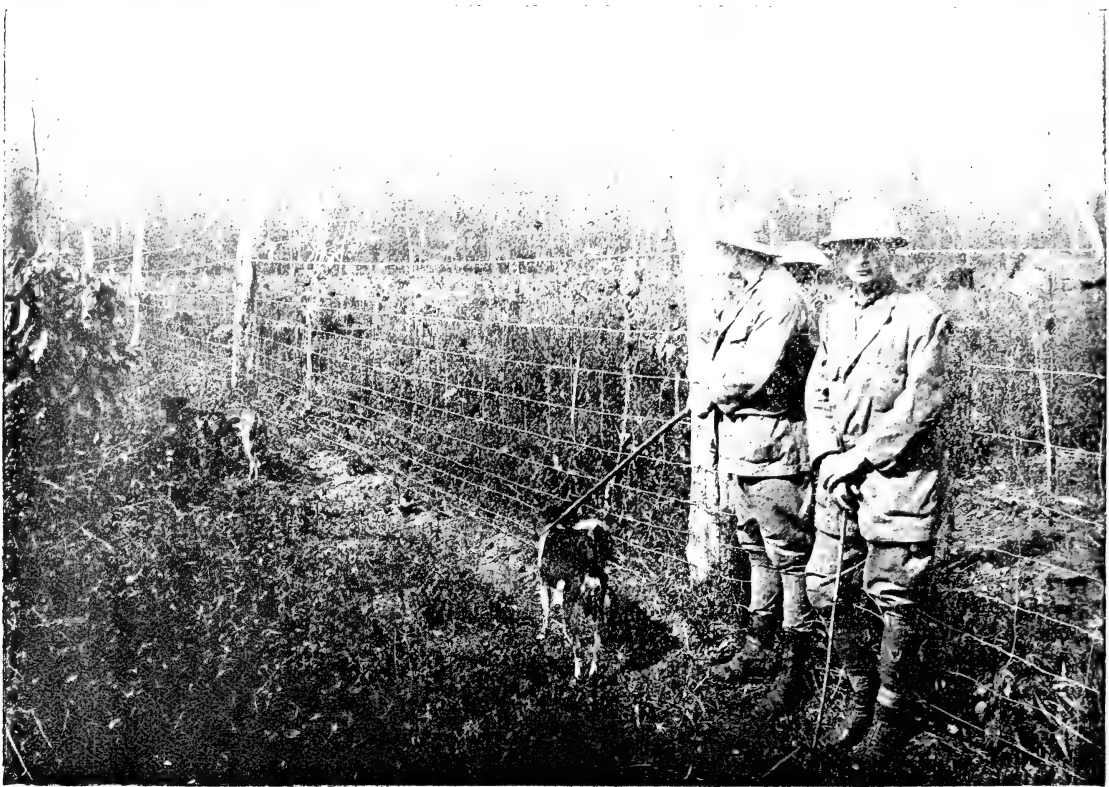


Photo by T. B. Chitrakar.

A fence of woven and barbed wire.

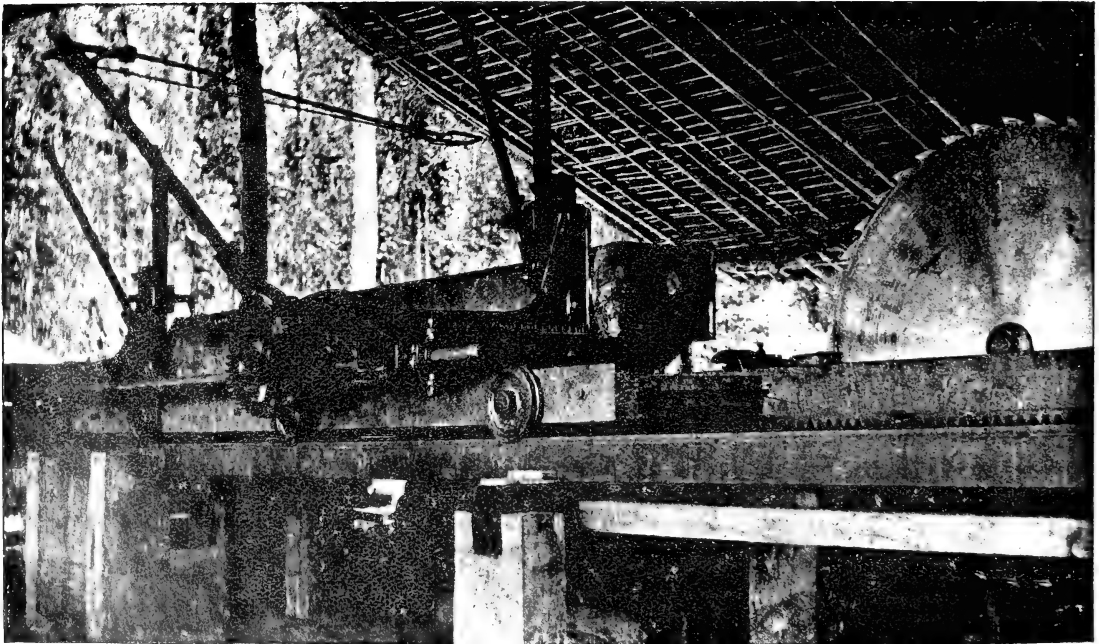


Photo-Mech. Dept. Thomason College, Roorkee.

Photo by L. E. S. Teague.

A semi-portable American saw-mill.

above it and another eighteen inches higher still. It is stretched on strong sal posts 30 feet apart and about three inches at the bottom of the woven wire is buried in the ground. This type of fencing costs about Rs. 1-2 to 1-3 a running yard including freight, posts, labour etc. or about Rs. 45 per acre for a square plantation of 50 acres. This is the initial cost and assuming that the wire will last for about ten years with two moves in that time (plantations have to be kept fenced for three years) the cost of fencing with moves and repairs is estimated at about Rs. 17 per acre where 50 acres are put out yearly. Even such a fence as this is not absolutely gameproof and a few determined animals will get in from time to time; elephant and rhinoceros trample it down, pig will get underneath if there is any trace of slackness in the lower strands, barking-deer jump through between the woven wire and the barbed strand and sambhur and bison occasionally clear the whole thing. I have measured a place where a full-grown bison had cleared 5 feet 8½ inches, an almost incredible jump for such a heavy animal. The damage done by the few animals that succeed in getting inside is, however, negligible and I have never seen any serious harm done to a sowing protected in this way. Various forms of wire fences are still being experimented with and it is not likely that the last word as to economy or efficiency has been said yet.

18. The average cost per acre of these "taungya" plantations is a question that will naturally be asked and it is unfortunately not easy to give a definite answer even now. If the cash-book items against each plantation are added up and divided by the acreage the results will vary from *nil* to Rs. 80 but most of the figures are misleading; either they overlook the value of free labour supplied by villagers who are really paid in wet cultivation and other privileges, or else they include the cost of experiments and, especially in the older plantations, expensive efforts to retrieve partial failure. (Newly recruited villagers are apt to go away without warning after reaping the first crop, leaving the Forest Department the choice between abandoning the plantation altogether or carrying on weeding and cleanings with expensive outside labour.) If no allowance is made for free labour the Buxa Division figures for establishing sal at Rs. 12 per acre may be accepted but this does not include the cost of wire fencing as the sowings to which this figure refers have been fenced by the villagers with bamboo etc. Although this fencing has answered the purpose there it is pretty certain that the majority of plantations, not being so fortunate with regard to game, will require wire. Recently an attempt has been made to find out what plantations really cost by entering in the plantation journal against each operation not only the cost but also the labour involved in terms of coolies per acre; the results are unfortunately not yet available and the most

reliable figures are those of the Cinchona Department whose coolies are paid at a fixed daily rate (men As. 4-6, women As. 3-6 and children As. 2-6). The cost of three established plantations including all expenses except European supervision and depreciation of tools are given below :—

	Rs.
137 acres	2,440=18 per acre.
155 „	3,462=22 „
100 „	2,087=21 „

These are all in the hills where fencing is unnecessary. By “ established ” is meant that no further attention other than remunerative thinnings are required ; between the 6th and 10th year a thinning is made in these plantations which yields about 750 stacked cubic feet of fuel to the acre the royalty on which, at Forest Department rates, would be Rs. 15 or Rs. 22 according to the situation of the forest. This early return does much to mitigate the cost of formation.

19. The financial advantages of Taungya over the Selection System may appear doubtful in the face of the high cost of formation and fencing quoted above ; nevertheless the following three points in favour of the former are worth consideration. Firstly, it is hoped that the profits from field-crops can be made to pay, directly or indirectly, a larger share of the cost in future. Secondly, the value of the even-aged forests which it is hoped to raise should be considerably greater than that of any of our existing forests and the rate of growth faster. Thirdly, the cost of exploitation under a clear-felling system is less than under a selection system and this advantage can be increased by the use of mechanical means such as railways, skidders and saw-mills. With regard to the first point, the villagers in some of the older felling series are beginning to take a keener interest in their dry crops, to our mutual advantage, and, in this direction, the wire fences, which are at least as useful to the cultivators as to us, are having their effect. The departmentally grown crops should this year give us an idea of the real value of fenced and cultivated forest soil for agriculture. The second and third points require paragraphs to themselves.

20. The rate of growth attained by young trees grown on clean land was not fully realized until experiments in temporary cultivation were made. Sal plants under these conditions average one foot in height in their first twelve months (they will grow a little taller in the open but the crops over them do not impair their vigour in any other way) 3 feet by the end of their second year and 7 feet by the end of the third after which a steady growth of about four feet a year is maintained as far as our observations on artificial crops go, probably until the height

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Photo by T. B. Chitrakar.

A train-load of fuel leaving the coupe.



Photo-Mech. Dept. Thomason College, Roorkee.

Photo by L. E. S. Tague.

The improvised skidder loading *Sal* logs. Fuel in the foreground. Logs previously "yarded" by the machine on the extreme right.

growth of the tree is approaching its limit. Estimates of the final results of these crops are perhaps hardly justified in the present state of our knowledge but it is believed that, with proper thinnings, it may be possible to grow 40 sal trees to the acre averaging 6 feet in girth in 60 years. In the case of soft-wood species the rate of growth is of course much faster, such trees as Lampati (*Duabanga sonneratioides*) and Gomari (*Gmelina arborea*) attaining 5 or 6 feet in height in their first 12 months and, if spaced six feet apart, forming a complete canopy some 14 feet above the ground during their second year. The rotation proposed for the fast growing species is 40 years.

21. A comparison between the cost of extraction by carts under Clear-felling and Selection working has been possible this year as departmental extraction has been carried out in both types. The cost of felling, dressing, loading and carting one day's journey (under ten miles) is four annas a cubic foot for clear-felling against six for selection, the difference being due to delays in clearing temporary cart-tracks and loading, which is done by the carters themselves working in parties of five or six. It is not possible yet to give figures for a comparison between the cost of extraction by mechanical means and that of extraction by carts and manual labour as the former has been introduced too recently but it seems likely it will pay us, now that we have gained sufficient confidence in the taungya system not to be afraid of extensive clear fellings, to employ methods on the lines of American lumbering operations. A company for the manufacture of ply-wood and other products in the Buxa division has put in a light railway fed by three American skidders but the area of the annual coupe in this case is about three square miles and conclusions drawn from their results will not necessarily apply to the much smaller coupes, averaging about 70 acres, necessitated by local conditions in most parts of Northern Bengal. A siding from the Darjeeling Himalayan Railway (2ft. gauge) has this year been laid into a clear-felling coupe of 46 acres and, if successful, will be extended into each annual coupe in this felling-series. By this means sal logs are railed to the terminus of the metre-gauge line (shortly to be converted into broad-gauge) where a sale dépôt is being established. Fuel is booked to various destinations on the narrow gauge, mostly to Kurseong, a station at an elevation of 5,000 feet, where, in spite of the heavy freight inevitable on a mountain railway, it competes with local fuel which has to be carried in by coolies. On this siding a steam hoist borrowed from the railway has been used as a "skidder" for dragging logs to the rail and loading them on trucks at a cost of less than half that of carts and hand haulage. This same useful engine has been tried for dragging a stump-jumping disc-plough of Australian design and, if a satisfactory system of anchoring the cable blocks

can be devised, this should prove an economical means of giving the land its first cultivation. A semi-portable saw-mill of American design is being tried and appears to be well suited to cutting tea-box planking for which there is a strong demand. These small experiments should give us an idea of the type of outfit suited for extraction, conversion and, possibly, cultivation in our small coupes.

22. In conclusion, it seems reasonable to hope that a system of intensive taungya, besides overcoming the difficulties of reproduction, will increase the revenue by concentrating exploitation if not by inducing faster growth. The system seems well adapted to local conditions for the even-aged forest crops, by maintaining a close canopy, keeping down weeds and, until this canopy has formed, the ground is kept clean by profitable field-crops, thus increasing the advantages and decreasing the disadvantages of the rapid growth of vegetation of all kinds induced by the moist Bengal climate; for it must not be forgotten that this luxuriance is not an unmixed blessing and the fact that a valuable sapling may attain a height of 8 feet in its first year is to some extent discounted by the fact that the same climate produces climbers capable of pulling down 8-foot saplings in a few months.

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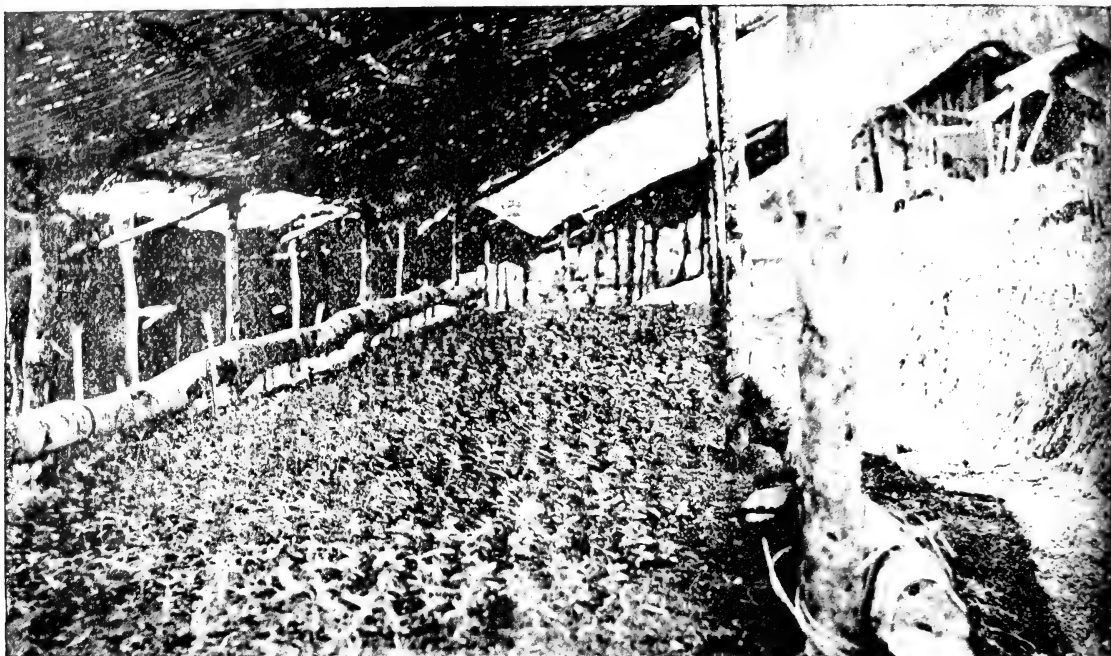


Photo by L. E. S. Tague.

A pricking-out bed with mat shades. The seedlings are *Eucalyptus Globulus*.



Photo-Mech. Dept. Thomason College, Roorkee.

Photo by P. Walsh.

Method of pricking-out showing the planting-board. At the extreme top of the picture is shown the plank on which the woman is sitting above the finished rows.

PART III.

General Notes on Nurseries and Planting in Bengal.*

BY

P. T. RUSSELL, L. E. S. TEAGUE AND E. O. SHEBBEARE.

Good nurseries and nursery work are just as essential for raising forest trees as for any other class of plants.

Site.—In the hills a northerly aspect is desirable below 4,000 ft., above this altitude a westerly or south-westerly aspect is best. The rainfall in Bengal is 120 to 200 inches and northerly aspects above 4,000 feet are very moist and cold. A water supply is essential in the hills though not absolutely necessary in the plains where successful work, with some species, has been done in waterless areas. The question of soil is of little importance as the plants are mostly grown in soil prepared with leaf-mould and, for the same reason, a nursery can never become exhausted and a good site is only abandoned when the planting area has moved too far away. Mr. Russell has found that a rotation of crops, in the seed bed is important and the same species should not be put in a bed two years running. The area must be fenced.

Laying out.—The beds should run from east to west in the plains, in the hills they must, of course, follow the contour. They should be made in continuous lines six feet wide with only a few narrow cross-paths intersecting them but, between the beds, a gangway three feet wide should be left. It is a mistake to crowd the beds closer than this as side light and free circulation of air are most necessary. In the hills the land must be terraced ten feet wide. In large nurseries it is convenient to lead water in bamboo pipes to a series of sunken barrels down the middle of the area.

*Note by Mr. Shebbeare.—

The original nursery notes were written by me chiefly from verbal information supplied by Mr. Russell who also corrected them when finished—whatever was from my own notes related to plains species. Later, when Mr. Russell had left the district, Mr. Teague and I rewrote the whole with additions from our own notes, chiefly concerning the upper hills, plains, and Chittagong.

A copy of this was sent to Mr. Russell for correction and another copy corrected in consultation with other forest officers at an informal conference. Shortly after this Mr. Russell sent me a copy of his notes on the middle and foot hills nursery work with the suggestion that it might either be printed as it stood or incorporated in the other note. I followed the latter course and hope I have included all the main points but there has not been time to send the whole note to Mr. Russell for revision.

Area.—Twelve running feet of bed six feet wide, locally known as a “*kamra*,” is taken as the unit of area for nursery work. For six-foot-by-six-foot planting it may be taken that two such “*kamras*” will be required for each acre of planting area. This allows for both seed and pricking-out beds as well as some margin for contingencies. On this assumption one acre of nursery will serve for about 200 acres of planting unless the plants have to be kept for more than a year in the beds as is the case with some species above 5,000 ft.

Preparation of seed-beds.—The beds must be hoed one foot deep, all roots removed and the surface levelled. Leaf mould should be collected in the cold weather and spread out to sweeten. Beds should, if possible, be made up before the rains break. They consist of a six inch layer of leaf mould mixed with the local soil, screened and spread over the hoed-up surface of the land. By varying the proportion of leaf mould to soil it is possible to force on or retard growth, an important point with some species. Poles or planks round the edges of the beds to prevent the mould from falling are often employed though condemned by some as being likely to cause water logging.

Shading.—Except in the case of the larger seeds it is necessary to shade the seed beds and, at low elevations and in the case of slow growing seedlings, pricking-out beds require shading also. Trees bearing small seeds are *Alnus nepalensis*, *Cryptomeria* and others, especially *Betula cylindrostachys* and *Duabanga sonneratioides*. Cover from the drying sun of the hot weather and the heavy downpours of the monsoon is most essential for raising seedlings of such species successfully.

In all cases shades should be removed from the pricking-out beds some time before the plants are to be taken up so that the shock of being transplanted and the shock of being exposed to full sunlight for the first time do not come simultaneously. This hardening process can be made still more gradual by removing the mats one at a time, where two thicknesses are used.

In unshaded beds, thatch grass is sometimes spread on the surface and removed after germination to keep the soil moist. Shades should slope from six feet on one side of the bed to three feet on the other, the higher side being to the north in the plains and usually towards the hill-side in the hills, though in certain circumstances it may be better to face them outwards. They are made of thatch grass, wherever this is available, as it is cheaper and better than bamboo mats which, however, possess the advantage of being easily removed and replaced. A suggestion to use one of the several makes of flexible roofing material has not yet been tested. To the posts supporting the shades horizontal poles are lashed a few inches above the level of the bed to support a plank from which

weeding and other operations are carried out. Beds narrow enough to allow of reaching across have been tried but are not found to be economical.

Sowing.—Small seeds are sown broadcast after watering the beds and a light layer of mould sifted over them; large seeds are dibbled in at even depth and spacing, the general rule being that the upper surface of the seed should be at a depth equal to the diameter. Seeds should not be sown too thickly, except in the case of *Terminalia myriocarpa* which is a bad germinator.

Some species are planted out direct from the seed-bed but the majority are pricked out three inches by three inches into another bed as soon as they can be handled, that is to say, when they are about three inches long, including the roots.

Seeds treated with red lead are less likely to be attacked by pests.

Pricking-out.—This term has become universal though the process described below is generally employed as being less likely to lead to the doubling up of the roots than simply dibbling the plants into the beds.

The operation is done with a planting-board, a piece of planking six feet long and three inches wide with a notch cut every three inches along one of its edges. The planting board is laid across the width of the bed and a trench, somewhat deeper than the roots of the seedlings, made along the notched edge. A seedling is held in one of the notches and the trench filled in to hold it upright. The object of pricking-out is to produce well developed, well balanced plants with a comparatively large and fibrous root system.

Weeding and watering.—It is most necessary to keep the beds thoroughly weeded. This is necessary in seed beds as soon as germination is complete and in pricking-out beds about a fortnight after the plants have been put in, and thereafter in both about once a fortnight. It is best done by women who loosen the soil round each plant at the same time with a pointed stick. After this operation the plants at once make a decided spurt.

In most cases watering is also necessary in the dry season but considerable care must be taken not to overdo this as too wet beds cause damping off and growth of moss and it is probable that more plants are killed by over watering than by drought. Watering should be done in the afternoon in the plains and in the forenoon in the hills (on account of the danger from frost). A watering can with a very fine rose (preferably Haw's patent) is necessary.

Each nursery should be in the charge of a *mali* doing whole time work.

Planting and sowing at stake.—Planting holes, locally known as “thalis”, are usually spaced six feet by six feet apart. As loosened soil and freedom from roots are the main factors in making a plant come on quickly, the deeper the holes the better. (Mr. Russell holds that it pays to make the “thalis” 18 inches square and deep though the Forest Department does not usually make them so large.) The holes should be dug at the end of the cold weather and the soil, which has been freed of weeds and stones, left for about a month at the side of the hole but filled in again before heavy rain occurs, leaving the loosened earth in the middle of the “thali” standing some six inches higher than the surrounding ground to prevent water logging. Plants are lifted from the nursery bed with a handful of mould; this is effected by watering the bed more heavily than usual for two or three days before lifting.

The best time for planting is the end of May or beginning of June for localities above 5,000 ft., the middle of June up to the middle of July in the middle and foot hills and the same period in the plains except that it is safe there to plant up to the end of August. The best size of plant is from four to six inches high. It might be thought that such small seedlings would not stand planting in the open but experience has shown in Bengal that the only safe and successful way of planting is to put out small seedlings. A few kinds may safely be kept in nurseries for a year or more; they are *Bucklandia*, *Cryptomeria*, *Juglans* and perhaps *Michelia*. They will be uncovered and exposed to full light during the open season preceding their removal to the forest.

In planting great care should be taken to ensure that the roots are not doubled up and that the level of the earth round the plant reaches the same height in the “thali” as it did in the bed. When planting is finished and the soil has been thoroughly well pressed down, the centre of the “thali” should stand only very slightly above the surrounding ground level, this to prevent its settling down into a basin but it can be easily over-done with the result that the upper part of the roots become exposed after heavy rain. For sowing at stake the “thali” should be prepared in the same way, the seeds in each “thali” being sown well apart, so that excess seedlings can be transplanted without disturbing the one that is left. Stakes of split bamboo or stout sticks, to show the position of the “thali,” should be driven deep into the ground with a mallet and not merely pressed in by hand.

Boxes made of $\frac{1}{2}$ inch light wood and measuring 2 ft. \times 18 inches \times 4 inches are used for carrying the seedlings. They are carried on light wooden carriers two boxes on each carrier. At the planting site a woman or boy works with each pair of planters carrying the seedlings from the

boxes so that the balls of earth are kept intact, lifting by the collar of the seedling being avoided at all costs.

Tending.—The amount of tending necessary depends on the rate of growth of the species and on whether the intervening spaces are occupied by well cleaned field crops or by jungle. Under a good field crop practically no special tending of the forest plants is necessary except the loosening of soil about their roots, at any rate in the case of fast growing species, provided that two years' cultivation can be arranged for. In the case of sal grown with field crops, some forking or weeding may be necessary and climber cutting will have to be done in the third year. If the area is not under field crops, jungle must be kept sickled back well away from the plants; two weedings will be necessary during the first rains, one in the second and one in the third. In the case of sal even more weeding will be necessary.

Weeding and cleaning is best done at the beginning and the end of rains. If only one cleaning is to be given it should be at the end of the rains. It is a good plan when making this final cleaning to spread 3 or 4 inches of cut jungle over the forked-up "thali" as a mulch and to cover this with a thin layer of earth. Only such jungle as will decay quickly should be used. Illami (*Aggeratum* species) forms an excellent mulch and is generally plentiful. Mulching is particularly advisable on dry ridges into which the roots have not penetrated to any great depth so that the trees are likely to die off through lack of moisture in the dry weather.

The result of this tending is that most of the small trees go away with a straight leader and form symmetrical trees such as are not always seen in plantations set out with one or two year old seedlings.

General.—As a general rule the quicker the saplings can be established the cheaper and more satisfactory will the work be, and labour is more economically employed in forcing the plants on in their early stages than in keeping them alive once they have had a set back. In experimenting with untried species it may be taken as a rule that the seed and not the whole fruit is what should be sown, and, if the seed does not ripen at such a time as to allow of plants six to eight inches high being produced by the beginning of August (in the plains) or the middle of July (in the hills), experiments in storing the seed should be made. In most cases thoroughly dried seed can be stored for some time if it is not exposed to extremes of temperature or to damp.

The commonest mistakes in nursery work are:—bad organization (e.g. insufficient pricking-out beds for the number of seed beds), beds too narrow, paths too numerous and narrow, shades too low, over watering and under weeding. The commonest mistakes in planting are:—too

big plants, doubling up the roots, leaving the top of the "thali" as a depression, making the "thalis" too small and not pressing the soil down firmly enough round the plant.

NOTES ON THE SPECIES.

Acacia Catechu.—Khair in all vernaculars. River beds up to 1,000 ft. Seeds January. If sown direct the seed is stored in sacks until the end of May when it is sown after soaking in water for two days. The seed is separated from the pod. It may be sown direct in cultivated lines. There is no information as to nursery work but it can probably be sown earlier if water is available. If sown in May it should reach four feet by the end of August. 11,000 seeds to the ounce.

Acer Campbellii.—Kapasi in Nepalese 5,000 to 9,000 ft. Seeds November and December. Collect the seed from the tree, dry and store it for sowing in February and March, in nurseries under shades. Prick out in May. It should be four inches high by June and should be planted out at the beginning of the following rains. This species is one of the few which are easy to grow at elevations above 7,000 ft. 1,350 seeds to the ounce.

Acrocarpus fraxinifolius.—Mandani in Nepalese. Foot-hills up to 4,000 ft. best at 2,000 ft. Seeds March to May. Sown either in the nursery or direct. Russell recommends the latter and has had excellent results sowing in "thalis" on a dry exposure in April and May. The Forest Department has also had good results sowing both in "thalis" and broadcast in burnt coupes. Plants, some of them five feet high, transplanted in June in the plains never died back. If raised in the nursery, sow seed as soon as ripe. 6 lbs. of seed to the "kamra" produce about 4,000 seedlings which should be pricked out when big enough to handle and planted out in June of the same year. Shades are required on seed beds but not on pricking-out beds. Growth fast, at 2,000 ft. reaches 8 to 20 ft. in height in two and a half years. Grows very straight.

Albizzia procera.—Safed Siris in Nepalese, Koroi in Bengali. Near river beds in the plains. Seeds January-February. Sown when ripe. Six pounds of seed to the "kamra" gives 4,000 seedlings. 670 seeds per oz.

Alnus nepalensis.—Uti in Nepalese. 2,000 to 6,500 ft. especially on landslips. Seeds February. Sown in March in shaded beds and pricked out in May, also under shades. Below 5,000 ft. the plants can be put out in June or July of the same year but at higher elevations it is generally necessary to keep the plants in the nursery through the cold weather and plant them out at the beginning of the following rains. The experiment of putting the nursery at a lower elevation than the area to be

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Photo by L. E. S. Teague,
Gomari (*Gmelina arborea*) 18 months after sowing, at plains level.

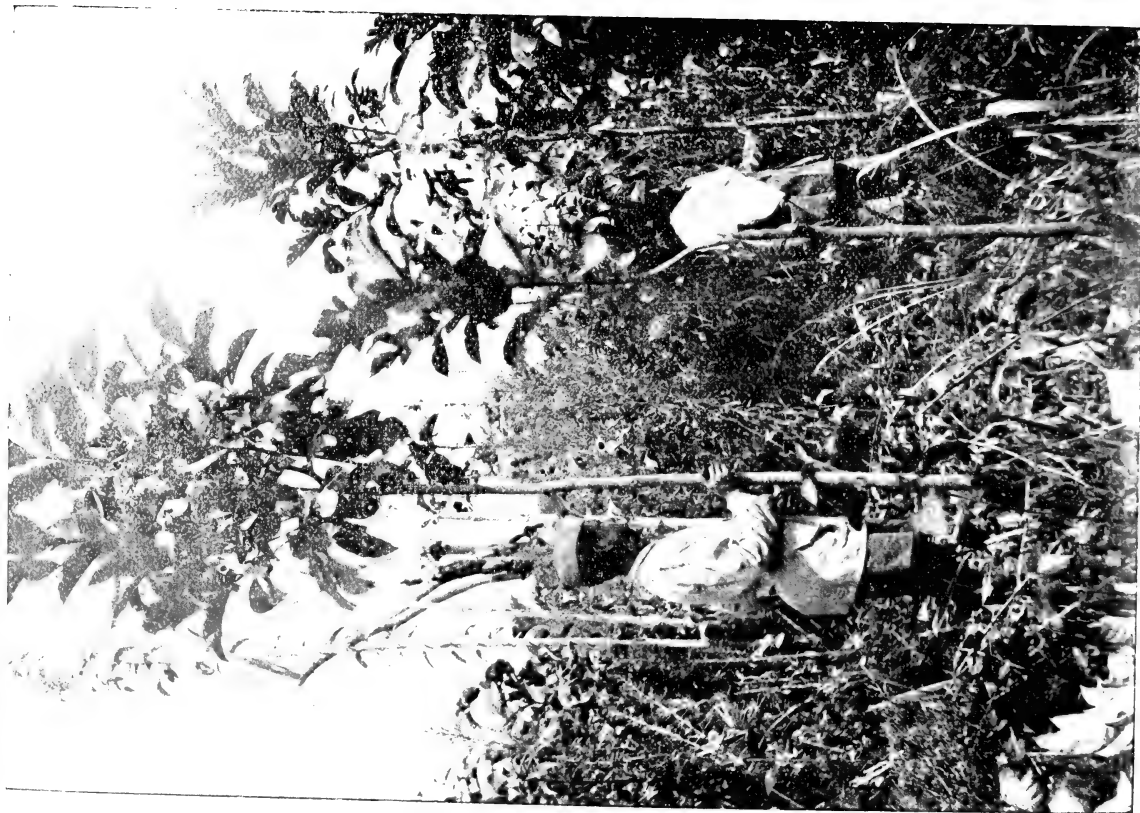


Photo-Mech. Dept. Thomason College, Roorkee.

Artocarpus Chaplasha 2 years old.
Direct sowing in taungya, Kaptai, Chittagong Hill Tracts.

planted with a view to forcing the plants is being tried. 8 oz. of seed to the "kamra" gives 8,000 seedlings. Slow to germinate. Shades may advantageously be removed from the pricking-out beds after the plants have been in them a short time. In the case of plants kept in the beds through the cold weather, shades must be replaced when danger from frost arises. Growth is very fast and continues throughout the year. At 6,000 ft. it attains a height of 4 to 9 feet one year after planting. Very susceptible to frost and grazing. May with advantage be underplanted with Pipli (*Bucklandia populnea*). 14,000 (?) seeds per oz.

Amoora Wallichii.—Lali in Nepalese, Pitraj in Bengali (Chittagong). Found in sal and mixed forest in the plains. Seeds May and June, rather difficult to collect as only large trees bear fruit and they are very tall. Seed is broken out of the fruit and dibbled 6"×6" in the nursery-bed in June. It germinates in three weeks. Shades are unnecessary. Direct sowing has been tried but seed was destroyed by rats. It should be tried again. It grows very fast and very straight.

Anthocephalus Cadamba.—Kadam in all vernaculars. Plains and foothills up to 3,000 ft. Seeds August-September (occasionally as late as December). The fruit is collected, allowed to rot and the pulp washed away leaving the seeds at the bottom of the bucket. Seed, if thoroughly dried, may be stored in a dry place and sown in February, this is preferable to keeping the plants in the nursery bed through the cold weather. 2 lbs. of seed to the "kamra" will produce 5,000 seedlings. It germinates in three weeks and is probably the fastest growing tree in the plains, giving a girth increment of about six inches per annum up to the seventh year.

Artocarpus Chaplasha.—'Latter' in Nepalese, Chama or 'Chappalish' in Bengali. Plains and hills up to 5,000 ft. Seeds July-August. Seeds must be sown fresh within three days after collection. It germinates well and is best sown direct, though a nursery bed, which should be shaded, is advisable for filling vacancies. Growth rapid after the first rains, attaining 3 to 4 ft. in twelve months and 8 to 12 ft. in twenty-four, 50 seeds per oz.

Betula cylindrostachys.—Birch; Saur in Nepalese. Foot hills to 6,000 ft. especially on landslips. Seeds in February. Treatment the same as for *Alnus nepalensis* q. v. 8 oz. of seed per kamra will give 10,000 seedlings. Very fast growing; the average girth of dominant stems in a 12-year old plantation at 4,000 ft. (Mongpoo) was 3 ft. 2 ins. and they were very tall. 250,000 (?) seeds per oz.

Bischofia javanica.—Kainjal in Nepalese, Uriam in Bengali (Chittagong). Plains up to 5,000 ft. especially on silt near rivers in the plains. Fruits December and January. Sow rather thinly in nurseries under shades

and plant in July direct from the seed-bed without pricking-out. 12 lbs. of seeds will sow a kamra and produce about 4,000 seedlings. Growth moderately fast, 2 to 3 feet in 12 months and 6 to 8 ft. in 24. Very susceptible to damage by game. It appears to grow throughout the cold weather. To illustrate the importance of shades it is worth recording that, at Sukna, 3 beds were left unshaded and 3 were shaded; nothing germinated in the unshaded, and all germinated in the shaded. It was a dry year and no watering was possible in the nursery. 2,650 seeds per oz.

Bombax malabaricum.—Simal in all vernaculars. From the plains (where it prefers a light soil near big rivers), up to 3,000 ft. Seeds March and April, and is sown direct as it appears to transplant badly. It germinates in 4 days and grows very fast. In the Lakhimpur taungya, (Assam) 18-month old trees were from 8 ft. to 15 ft. high and trees in their third year up to 30 ft. high. Damaged by game. It is said to require a lot of room, and, in Assam is planted 26 ft. \times 26 ft. In Bengal they are planted 6' \times 6'. It is best grown in a mixture and is being tried with Gomari and Sissoo. 780 seeds per oz.

Bucklandia populnea.—Pipli in Nepalese. Between 3,000 and 7,000 ft., but best between 4,000 to 6,000 ft. Seeds all the year round, generally large quantities available in January. Should be sown in March, pricked out in July and planted not later than the middle of the following June or, at high elevation, may be kept for 2 years in the nursery. Shades are necessary over seed beds but not necessary over pricking-out beds except perhaps in the hail season. Growth slow for the first two years, fairly fast later especially at lower elevations. At 4,500 ft. at Mongpoo 6-year old trees are about 10 inches in girth. Attacked by deer. A strong shade-bearer. Is being tried under Utis. 7,600 seeds per oz.

Castanopsis Hystrix.—See under Quercus.

Cedrela Toona.—Tuni in Nepalese, Surajbet in Bengali (Chittagong). Plains forests where it prefers a light soil in the neighbourhood of large rivers. Seeds May and June 2 lbs. of seed will sow a kamra and produce 6,000 seedlings. Both seed and pricking-out beds should be shaded but shades should be removed early from the latter. Owing to the seed time the young plants are not big enough to be planted in their first rains (like *C. microcarpa*) but they stand transplanting in the cold weather if root-and-shoot pruned. Seed has also been stored until the following season successfully. It germinates in a week or fortnight and the tree is easy to grow but suffers badly from the twig-borer and is therefore not usually planted pure. It grows 2 to 3 feet in 12 months and 8 ft. in 24.

It is badly grazed by game. A moderate shade-bearer. 7,150 seeds per oz.

Cedrela microcarpa.—Tuni in Nepalese. Foot-hills up to 4,000 ft. very similar to the last in most respects but the seed time, February to March, allows of its being planted in its first rains, and it is a poor shade-bearer. Prick out seedlings by the end of May and plant early in August. It is said to be faster growing than the last.

Chickrassia tabularis.—Hallureh-tun in Nepalese but, owing to confusion between the various sorts of Hallureh, the Bengali name, Chikrassi, is generally used now. Well drained soil in the plains and up to 3,000 ft. Seeds end of December. Fruit is collected and dried in the sun when seeds can be extracted. Sown in February, about 1 lb. to the kamra, in a shaded nursery. It germinates in about 6 weeks and is pricked out when two or three inches high into another shaded bed. It should be planted in June or July but will stand cold-weather planting if necessary. Very easy to grow and grows very straight even in the open. Rate of growth about the same as Toon but it is much less damaged by the twig-borer.

Cinnamomum cecicodaphne.—Malagiri in Nepalese. Gandroi in Bengali. Alongside perennial streams in the plains and up to 4,000 ft. A few trees have been found in Ramam Block (6,000 ft.). Seed collected from the tree in October and sown at once in shaded beds, after removing the pulp. There is difficulty in getting sufficient seed as the tree is scarce and the fruit eaten by parrots. Transplants well. 50 seeds per oz.

Cryptomeria japonica.—Usually called Dhupi by the Nepalese (at Mongpoo it is called Tarpin). An introduced species which does well at 4,000 to 8,000 ft. but best at 5,000 to 6,000. Seeds collected October and November and sown in shaded nurseries in February. It germinates in a month and is pricked out in shaded beds in May and June. It is planted in May or June of the following year when 6 to 8 inches high. Until 3 years old its growth is rather slow but after that very rapid and plantations of this species probably have higher increment to the acre than those of any other at the elevations at which it grows. The 24-year old trees in the plantation at Sureil (5,000 ft.) average 3 ft. 3 ins. in girth; the best are 4 ft. 6 in. There is copious natural regeneration wherever there is sufficient light. 9,200 seeds per oz.

Dalbergia Sissoo.—Sissu in all vernaculars. Found naturally in river bed forests in the plains but does excellently wherever planted. Seeds January and February. Kept till the end of May and sown direct in the pods after soaking for two days. They germinate in about a week. They can also be transplanted when they are very young or larger plants

if the roots are puddled in mud. Plants attain 2 ft. 6 ins. to 6 ft. in 9 months. Susceptible to damage by game. 500 pods per oz.

Dalbergia latifolia.—Satisal in Nepalese. On well-drained land west of the Tista from the plains up to 2,000 ft. Pods collected early in March, broken out and sown in shaded nursery beds at once. It germinates well. It is pricked out in shaded beds and is big enough to plant out in July. The tree is very scarce now owing to its having been cut out in the old days. Said to be of slow growth at first.

Duabanga sonneratioides.—Lampati in Nepalese, Bandarhola in Bengali. Lower hills up to 3,000 and occasionally on the sides of perennial jhoras in the plains. Often found on landslips, embankments, etc. Seeds April and May. Collect the fruit just as it ripens and begins to open drying it in the sun for two days with a cloth over it to prevent the seed from being blown away. The seeds which are very minute, have been successfully stored till the following season in an artificially warmed godown by Mr. Russell. This obviates keeping the plants in the nursery through the cold weather. It is usually sown in a nursery under shades (2 lbs. of seed to the kamra yields 6,000 seedlings) and pricked out when about three inches high. Sowing with ashes and red lead as a protection against ants is recommended. As this tree comes up naturally on mineral soil (landslips and embankments), experiments were tried in growing it in beds of subsoil without any leaf mould. Experiments for two years seem to show that germination is better on subsoil and this also reduces the amount of weeding necessary. Seedlings are delicate at first and apt to damp off so that some care in the regulation of watering is necessary. One of the fastest growing trees in the foot-hills; two-year-old trees attain 12 to 15 feet; a 7-year-old tree at 2,000 ft. (Mongpoo) measured 4 ft. 2 ins. in girth; the average girth of dominant trees in a 9-year old plantation (Riyang) was 3 ft. 1 in. these trees were about 50 ft. in height. 723,000 seeds per oz.

Eriobotrya petiolata.—Maya in Nepalese. 6,000 to 8,000 feet. Seeds in November. Sown early in February in unshaded beds and pricked out early in May. Plants should be 4' 6" high by the end of May and should be planted in June. It has also been sown at stake successfully.

Gmelina arborea.—Gomari in Bengali, Khamari in Nepalese. Plains and lower hills up to 3,000 ft. Grows best on light silt in the neighbourhood of rivers. Seeds April and May. The fruit is picked up from the ground and sown half an inch deep, either direct or in unshaded beds 3 inches apart, after removing the pulp. The use of leaf mould in the nursery is unnecessary. The usual method is to sow direct with a nursery for filling vacancies. Seed can be stored for a year if thoroughly dried at the start and in this way very early plants can be obtained. Seed

germinates in about ten days. The stripping of all leaves and branches with the exception of the leading shoot in the first cold weather probably strengthens the leading shoot and reduces the food supply of a defoliator which always attacks this tree. Very fast growing; it should attain 6 to 8 ft. in 12 months and 15 ft. in 24 but in very favourable circumstances (at Kaptai, Chittagong Hill Tracts) it attains 25 to 30 ft. in 24 months. It is very susceptible to damage by game and cattle. 40 seeds to the oz.

Hovenia dulcis.—Bangī in Nepalese. Lower hills up to 4,000 ft. Grows best in jhoras and low valleys with good soil. Seeds December to January. Seed must be well dried and sown in shaded nurseries in March. It germinates in 10 days and grows fast reaching 9 inches to a foot in three months from the time of sowing. It reaches 6 to 8 ft. in 18 months on Mongpoo.

Juglans regia.—Walnut, Okhar in Nepalese. Grows best from 3,000 to 6,000 ft. in jhoras and especially on old charcoal kiln sites. May be sown direct or in nurseries, the latter is better especially near villages as children dig up the walnuts to eat. At high elevations (5,000 to 6,000 ft.) it is usually sown in unshaded beds in February or March and should be 8-10 ins. high by the end of May. It is sown about an inch deep and three inches apart so that pricking out is not necessary. It is transplanted in the cold weather when leafless. Some walnuts sown in December at 2,500 ft. (Buxa) germinated in 5 weeks. Walnuts sown above 4,000 ft. would probably not germinate before April. In an experiment (Toong coppice) with beds containing leaf mould and beds of ordinary soil, it was found that the walnut in the former failed entirely while there was perfect germination in the latter. Further experiments in this direction should be made before accepting this conclusion finally. Growth rapid up to the sapling or small pole stage at any rate. 50 seeds per lb.

Lagerstroemia parviflora.—Sidha in Bengali, Borodhara in Nepalese. Plains up to 3,000 ft. especially on a strip a few miles wide along the foot of the hills. This species has not been much experimented with. The fruit is collected in February just before it opens, it is then dried and the seed removed and sown at once. 800 seeds per oz.

Lagerstroemia Flos-Reginæ.—Jarul in Bengali. Occurs naturally in Chittagong Hill Tracts and in the extreme east of the Buxa Division. It grows sporadically along river banks and will grow on low swampy ground. It stands temporary submersion and is said to stand waterlogged soil. As a road side tree it appears to have done well in stations, especially Jalpaiguri. Seed is collected in February and March when the capsules are about to open. After drying the capsules they are broken

open and the seeds are dried in the sun for a few days. If water is available in the nursery the seeds should be sown in the beds at once and a very light layer of soil sprinkled over them. The seed can, if necessary, be stored in dry tins for a few months. It grows to 4 to 6 ins. by the beginning of June when it should be planted out. In Chittagong it grows to 4 to 5 ft. in two years. It has been very little tried in Northern Bengal during recent years but should not be lost sight of for filling moist hollows or places liable to submersion. Owing to its spreading habit close planting (4×4 or 5×5) is indicated. 4,580 seeds to the oz.

Machilus edulis or *Phæbe attenuata*.—Lepcha Kawla in Nepalese. 4,000 to 8,000 ft. The seeds, which are large, are collected in November or December. It seeds well about every third year. It is sown in February in unshaded beds about three inches apart and kept in the nursery until the rains of the following year when it is planted out. In Darjeeling Division it has been sown direct in April. Rate of growth fast.

Mesua ferrea.—Nageswar in Bengali, Nagasuri in Nepalese. Occurs sparingly in the plains and foot-hills between the Neora and Jaldhaka rivers in the Duars and also in the Chittagong Hill Tracts. Seed ripens August and September and will keep. It can be sown 4 to 5 inches apart in the seed bed so that pricking out is unnecessary. It germinates well but is very slow. 10 seeds to the oz.

Michelia Champaca.—Champ or Ouli champ in Nepalese. Plains up to 3,000 ft. Grows well in sal forest and in a type of wet mixed forest in which no other valuable species appears to thrive and it seems to be spreading rapidly under fire protection. Seed collected during the first half of August. It is said that the seed must be collected from the tree and not off the ground though some records seem to show that seed off the ground has given good results. Seed is always difficult to get. As soon as collected the pulp is washed off and the seed is dried in the shade. Seed can not be kept for more than a day or two and should be sown in shaded beds, pricked out in other shaded beds when a few inches high and kept in the nursery throughout the cold weather. It is planted out at the beginning of the following rains when anything up to 4 ft. high. The great drawback about this species, besides the difficulty of collecting sufficient seed, is the unfavourable season at which it ripens coupled with the fact that it will not keep. Experiments will be made this year to see if seedlings can be successfully put out when only a few weeks old in early September. Once established the rate of growth of this species is very rapid, it reaches a height of about 8 feet in two years and a tree near Sukna 5 ft. 6 inches in girth and 117 ft. high was found on



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Photo by R. S. Pearson.

Teak plantation, Kaptai, Chittagong Hill Tract, 1½ years old.

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elling to be only 36 years old. Another, in Buxa Divison, 9 ft. 4½ ins. in girth and 128 ft. high was 45 years old. 480 seeds per oz.

Michelia excelsa.—Champ in Nepalese. 6,000 to 8,000 ft., best at 6,500 to 7,500 ft. The fruit, which is plentiful most years, is collected in December to January, dried for a few days and after the pulp has been removed, spread on mats to dry and stored until the middle of February or early March. It is then sown under shades in a nursery and when a few inches high, pricked out 3"×3" in a bed which need not be shaded. They may be planted out either in December or June of its 2nd or 3rd year. With cultivation growth is fairly fast, after the 2nd year the plants putting on shoots of three to three and half feet yearly. It is very susceptible to damage by game and squirrels. 230 seeds per oz.

Morus laevigata.—Kimbu in Nepalese. Foot-hills up to 4,000 ft. and, rarely, on silt in the plains. Seeds ripen April and May and should be collected from trees known to give fertile seed as apparently all do not. 8 lbs. of seed per kamra will give 6,000 seedlings. If sown at once under shades and pricked out early also under shades the plants can be put out in August of the same year when about 4 inches high, otherwise they will have to be kept in the nursery through the cold weather and put out after root-and-shoot pruning early in the rains, a method which has often been employed though it is more expensive. The plant sends up one or more whippy shoots one of which stiffens up to form the tree. Growth fast and straight. Very susceptible to damage by game. It has recently been discovered that young trees from 5 years old and upwards have been much attacked by the larvæ of a longicorn beetle, specimens of which were sent to Dehra Dun for investigation. 12,250 seeds per oz.

Prunus nepalensis.—Arupati in Nepalese. 6,000 ft. to 10,000 ft. Sown early in February and pricked out when a few inches high, in beds which need not be shaded. It should be 8 inches high by the end of May but is slow after that. Put out in June. It can also be sown direct in March and April. Frost-hardy and not attacked by game.

Quercus and Castanopsis spp.—The following high-level oaks and chestnuts are those most commonly grown:—*Q. lamellosa* (Buk), *Q. lineata* (Phalat), *Q. pachyphylla* (Sungre katus), *Q. acuminata* (Arkaula) and *C. Hystrix* (Katus). All these grow from about 6,000 to 9,000 ft. except Arkaula which is found at 5,000 to 7,000 ft. Good seed years occur only about every three years and, owing to the attacks of insects, sound seed is always hard to obtain, especially that of Katus. The following method of treating seed gives good results. The fruit is collected in November and December and tested in a tub, those which float being thrown away. It is then thoroughly dried and stored in an earth pit. The top layer of seed in this pit should not be less than 2 ft. from the

surface and the rest of the pit filled up with subsoil (surface soil contains injurious insects). Before sowing the seed should again be tested in water and those that float rejected. In this way 80 per cent. germination has been obtained, otherwise germination is uncertain and sometimes delayed by as much as two years. If sown direct it should be dibbled, an inch or two deep, at the beginning of the rains. If sown in a nursery this should be done in February, without shades, and pricking-out is not necessary as the seeds can be dibbled a few inches apart in the seed bed. The plants are kept in the nursery at least 2 years, when they are planted after root-and-shoot pruning. This method overcomes the difficulty of poor seed years to some extent. It is said that the pruning is best effected by cutting the tap roots with a sharp spade, pushed horizontally from the side of the bed six inches below the surface, three weeks before lifting. The shoot should be pruned back to the collar when lifted. Phalat seed germinates earlier than that of the other species and if sown direct may be dibbled in March when it germinates in April or May. 7 to 18 seeds per oz.

Schima Wallichii.—Chilauni in Nepalese, Kanakin Bengali (Chittagong). Plains up to 5,000 ft. Seed ripe in February. 2 lbs. of seed to the kamra will produce 3,000 seedlings. Has been very little planted by the Forest Department but the Chinchona Department find that it gives a good yield of fuel to the acre. At Mongpoo (4,500 ft.) six-year-old trees averaged 1 ft. 2 ins. in girth.

Swietenia macrophylla.—This species of Mahogany appears to be a very promising tree in Chittagong where it has been introduced. The same or another species (probably *S. Mahagoni*) was tried several years ago in Northern Bengal with little success. The fruit ripens in February and early March and should be collected and dried for two or three days, then broken open and the seed removed. Sow at once three inches apart in shaded beds with the wing of the seed sticking out of the ground. No pricking-out is necessary and the plants are put out in May or June of the same year when they should be about six inches high. By the end of the first rains they attain a height of two to three feet, in two years eight to ten feet and in three years eighteen to twenty feet.

Tectona grandis.—Sagwan in Nepalese. Introduced with great success in Chittagong and, considering the lack of thinnings, the plantations in Northern Bengal (some of which at Bamonpokri date back to 1867), seem to warrant further experiment. Seed ripens in February and March and is abundant every year. It is collected and stored until the beginning of April when it should be soaked for 24 hours then spread in the sun on ground free from grass for 48 hours and again soaked. Repeat this operation of alternate soaking and drying 5 times, in all 15 days. Seed



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Photo by E. A. C. Modder.

Teak plantation, Kaptai. Chittagong Hill Tracts. Eight months old.

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is given out for sowing when soaking wet. This method has been found to give good and very even germination. Another method, said to be equally effective, is to dig a pit 2 or 3 ft. deep and 3 or 4 ft. square and fill it with water. When this has run out, line the bottom and walls with teak leaves. Soak the seed for 24 hours in water warmed by the sun during the day and put it into the pit with a layer of teak leaves between the layers of seed. Before filling the pit in this manner 5 bamboo water pipes, one in the middle and one from each corner, the latter laid aslant, are put in position so that, when the pit has been filled up and six inches of earth put over all, water can reach all the layers. The seed is kept in the pit for ten days and thoroughly watered every day. It is best sown at stake, 4 or 5 seeds well apart in the *thali* with a nursery, which should not be shaded, for filling vacancies. This should be done when the plants have 4 leaves besides the cotyledons. There is no need to wait until the rains break before sowing which may be done any time after the third week of March if the area to be sown is large, though probably the best time is the first week of April. The early growth is very rapid in Chittagong. It attains 2 to 4 ft. by the end of its first rains, 10 to 12 ft. by the end of the second rains, 20 ft. to 22 ft. by the end of the third and 30 to 32 at the end of the fourth. By its eighth year it attains 50 ft. or even more. In the Bamonpokri plantation dominant trees about 50 years old have a girth of 4 ft. 6 ins. to 5 ft. 6 ins. though they have suffered from insufficient thinning during a good deal of their life. One tree 53 years old has a girth of 7 ft. 2 ins. About the same girth has been attained in 25 years in Chittagong. Teak is badly defoliated by a caterpillar which has not yet been identified. It attacks the trees in May and June and strips every leaf. In young plantations in which the crowns have not closed up it is noticeable that the isolated trees are not so liable to the attack from which it is thought that mixture with a suitable shade bearer might afford protection. 50 seeds per oz.

Terminalia myriocarpa.—Panisaj in Nepalese. Foot hills up to 5,000 ft. It seeds early in January, only some trees producing fertile seed. 2 lbs. of seed to the kamra should produce 200 seedlings. It should be sown in March in shaded beds, thickly, as it germinates badly. It will then be ready to prick out in shaded beds at the beginning of May and put out in July. Its growth is rapid, at 4,000 ft. 6-year-old trees averaged 1 ft. 2 ins. in girth, the largest being 2 ft.

Tetrameles nudiflora.—Mainakat in Nepalese. Plains and foot-hills (especially the latter) up to 3,000 ft. Seeds March and April. 8 oz. will sow a kamra as the seed is very fine. It is said to germinate badly but it has not been tried much.

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[Part V

The Essential Oil from the leaves of *Abies Pindrow*, Spach.

BY

JOHN LIONEL SIMONSEN

FOR sometime past the investigation of the various sources of turpentine in India have been in progress in these laboratories (cf. Journ. Chem. Soc. Trans. 1920, *117*, 570). Recently a sample of the oil obtained by the distillation in steam of the leaves of *Abies Pindrow*, Spach. was received from Col. C. R. Johnson of Abbottabad and the results of the examination of this oil form the subject of this communication.

In other countries the oil obtained from the leaves, twigs and cones of the various species of *Pinus* and allied species form a valuable article of commerce under the general name Pine-needle oils (Perfumery and Essential Oil Record, 1920, *XI*, 97; Parry. Chemistry of Essential Oils, 1921, 53-61) and it appeared therefore to be a matter of interest to determine in how far similar Indian species resemble the European and American varieties. In many cases the oils, owing to their high content of bornyl acetate, are very fragrant and are in large demand as cheap perfumes, also owing to their low cost they have been used as flotation oils.

Some years ago Puran Singh (Ind. For. 1914, *XL*, 503) examined the oil from the fresh needles and short twigs of *Pinus longifolia*. The actual constituents of the oil, which was obtained in a yield of 1.4 per cent., were not determined, but its low ester content indicated that it would be of little value.

Abies Pindrow, Spach. occurs over a fairly wide area. According to Gamble, it is the principal western silver fir of the Himalayas and is found in the outer Himalaya from Chitral to Nepal from 7,000-9,000 feet rising occasionally to 10,000 feet. In the eastern Himalaya it is replaced by *Abies Webbiana* which rises to higher altitudes.

The results of the investigation of the oil from *Abies Pindrow*, Spach. have shown that it consists of over 70 per cent. of α - and β -pinene, whilst from the higher boiling fractions *l*-limonene, *l*-terpineol, *l*-terpinyl nonylate and two isomeric sesquiterpene alcohols have been isolated. Borneol and bornyl acetate were absent.

In view of these results the oil would appear to possess little commercial value, since it would be too expensive and could not be produced in sufficient quantity to serve as a source of turpentine.

Experimental.

The oil used in this investigation had been obtained by the distillation in steam in the usual manner of the leaves of *Abies Pindrow*, Spach. in a yield of 2.5 per cent. It was an almost colourless oil with a strong smell of turpentine and had the following constants:— D_{20}^{30} 0.8558, N_D^{30} 1.4667, $[\alpha]_D^{30}$ —10.38°, saponification value 5.3, saponification value after acetylation 15.44, acid value 0.3.

A quantity of the oil was distilled under diminished pressure (100mm.) when the following fractions were obtained:—

	Per cent.
A. 95-100°	62.4
B. 100-120°	27.6
C. Above 120°	10

Fractions A and B were systematically redistilled at the ordinary pressure (699mm.) using a fractionating column when ultimately the following fractions were separated.

	Per cent.
I. 154-158°	55.9
II. 158-160°	11.9
III. 160-164°	6.8
IV. 164-167°	4.2
V. 167-180°	10.3
VI. Above 180°	10.6 (combined with fraction C from original distillation.)

Fraction I.

This fraction after distillation over sodium had the following constants:— $D_{30}^{30} 0.8516$, $N_D^{30} 1.4634$, $[\alpha]_D^{30} +4.0^\circ$. It evidently consisted of d- α -pinene. The presence of this hydrocarbon was confirmed by the preparation of the nitrosochloride which melted at $111-112^\circ$ and gave on treatment with piperidine the nitrol-piperide melting at $118-119^\circ$.

Fractions II and III.

These two fractions were found to be a mixture of α - and β -pinene since on treatment with amyl nitrite a good yield of pinene nitrosochloride was obtained whilst on oxidation with potassium permanganate in alkaline solution nopinic acid was formed.

Fraction IV.

This fraction consisted apparently of nearly pure l- β -pinene. It only gave a very small yield of α -pinene nitrosochloride and when oxidised with alkaline potassium permanganate an excellent yield of nopinic acid melting at 128° was obtained. The identity of this acid was confirmed by conversion into nopinone in the usual manner. The l- β -pinene, after distillation over sodium, had the following constants:— $D_{30}^{30} 0.8508$, $N_D^{30} 1.4655$, $[\alpha]_D^{30} -14.75^\circ$. Camphene was found to be absent from this and the previous fractions of the oil.

Fraction V.

This fraction was repeatedly refractionated and ultimately a fraction was obtained which boiled fairly constantly at $165-175^\circ/700\text{mm.}$ After distillation over sodium it boiled at $167-171^\circ/700\text{mm.}$ and had the following constants:— $D_{30}^{30} 0.8455$, $N_D^{30} 1.4682$, $[\alpha]_D^{30} -62.83^\circ$. The boiling point and the constants indicated the presence of l-limonene and the presence of this hydrocarbon was proved by the preparation of the characteristic tetrabromide which after crystallisation from ethyl acetate melted at $103-104^\circ$. The identity of this tetrabromide was established by admixture with an equal quantity of d-limonene tetrabromide when dipentene tetrabromide was obtained, which melted at $123-124^\circ$. The presence of l-limonene was also confirmed by the preparation of the α -nitrosochloride melting at $103-104^\circ$ and the β -nitrosochloride melting at 100° . On treatment of the β -nitrosochloride with piperidine the nitrol-piperide was prepared which was separated

into the α -nitrol-piperide melting at 93-94° and the β -nitrol-piperide melting at 110-111°. Judging from the somewhat low optical activity dipentene was probably also present in this fraction but it was not found possible to isolate any derivatives of this hydrocarbon.

Fraction VI.

This fraction which boiled above 180°/699mm. was refractionated under diminished pressure (60mm.) and the fraction boiling below 150° collected separately. This fraction on distillation at the ordinary pressure (699mm.) was found to boil mainly between 200-240° and had the following constants, D_{20}^{20} 0.9203, N_D^{20} 1.4732, $[\alpha]_D^{20}$ -29.03°.

These constants indicated that the oil was probably a mixture of an alcohol and an ester. It was therefore hydrolysed with an excess of alcoholic potassium hydroxide solution and the resulting oil distilled when the main fraction passed over between 195-220°/697mm. This fraction consisted essentially of terpineol since it yielded a nitrosochloride melting at 112-113° which on treatment with piperidine gave a nitrol-piperide melting at 159-160°. In order to determine whether borneol was present the terpineol was converted into terpin hydrate by treatment with dilute sulphuric acid. A careful examination of the products of the reaction failed to reveal the presence of borneol.

The alkaline solution from which the terpineol had been isolated was concentrated on the water bath when, on acidification with dilute sulphuric acid, a liquid acid separated. The acid was purified by distillation in steam, in which it was slowly volatile, and fractionally converted into the silver salt. Three fractions were obtained which showed on analysis the following percentages of silver I. 39.8, II. 40.6, III. 42.1. Fractions I and II agree well for the silver salt of nonylic acid which requires Ag=40.7 per cent. These results indicate the presence of terpinyl nonylate in this fraction of the oil and the presence of this ester was confirmed by the isolation of terpinyl nonylate from the higher boiling fractions (see below).

The fraction from which the terpineol and terpinyl nonylate had been separated and which boiled above 150°/60mm. was repeatedly refractionated when ultimately three main fractions were obtained (a) 140-145°/50mm., (b) 155-160°/50mm., (c) 180-190°/50mm. Fraction (a) consisted of nearly pure *terpinyl nonylate* since on analysis it gave the following figures :—

0.1397 gave 0.4046 CO₂ and 0.1414 H₂O C=78.0, H=10.9.

C₁₉H₃₄O₂ requires C=77.5, H=11.5 per cent.

On hydrolysis with alcoholic potassium hydroxide solution in the usual manner an oil was obtained which distilled constantly at 213-217°/697mm. and consisted apparently of a mixture of *r*-terpineol and *l*-terpineol ($[\alpha]_D^{30} -22.14^\circ$).

On treatment with amyl nitrite *r*-terpineol nitrosochloride melting at 112-113° was isolated from which the nitrol-piperide melting at 159-160° was prepared. Derivatives of *l*-terpineol could not be obtained.

The alkaline solution gave on acidification nonylic acid which boiled at about 250° and gave a silver salt which showed on analysis 40.3 per cent of silver, whereas $C_9H_{17}O_2Ag$ requires $Ag=40.7$ per cent. Fraction (*b*) consisted essentially of a sesquiterpene alcohol and gave on analysis the following figures:—

0.1123 gave 0.3354 CO_2 and 0.11 H_2O $C=81.5$, $H=10.8$.

$C_{15}H_{24}O$ requires $C=81.8$, $H=10.9$ per cent.

The oil which was somewhat viscid and pale yellow in colour had the following constants:— $D_{20}^{30} 0.9076$, $N_D^{30} 1.4807$, $[\alpha]_D^{30} -7.72^\circ$. Fraction (*c*) consisted of an isomeric sesquiterpene alcohol and gave on analysis the following figures:—

0.1277 gave 0.385 CO_2 and 0.1309 H_2O $C=82.2$, $H=11.4$.

$C_{15}H_{24}O$ requires $C=81.8$, $H=10.9$ per cent.

The constants of this sesquiterpene alcohol were notably different from those of its isomeride $D_{20}^{30} 0.9259$, $N_D^{30} 1.4915$, $[\alpha]_D^{30} +8.1^\circ$.

All attempts to prepare crystalline derivatives of the two alcohols were unsuccessful and they were not further investigated.

The thanks of the author are due to Messrs. Gopal Rao and Ghose for assistance in the analytical work.

Forest Research Institute, Dehra Dun.

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VOL. VIII

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THE

INDIAN FOREST RECORDS

The Essential Oil from the leaves of
Abies Pindrow, Spach

By

JOHN LIONEL SIMONSEN,

Forest Chemist at the Forest Research Institute, Dehra Dun.



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